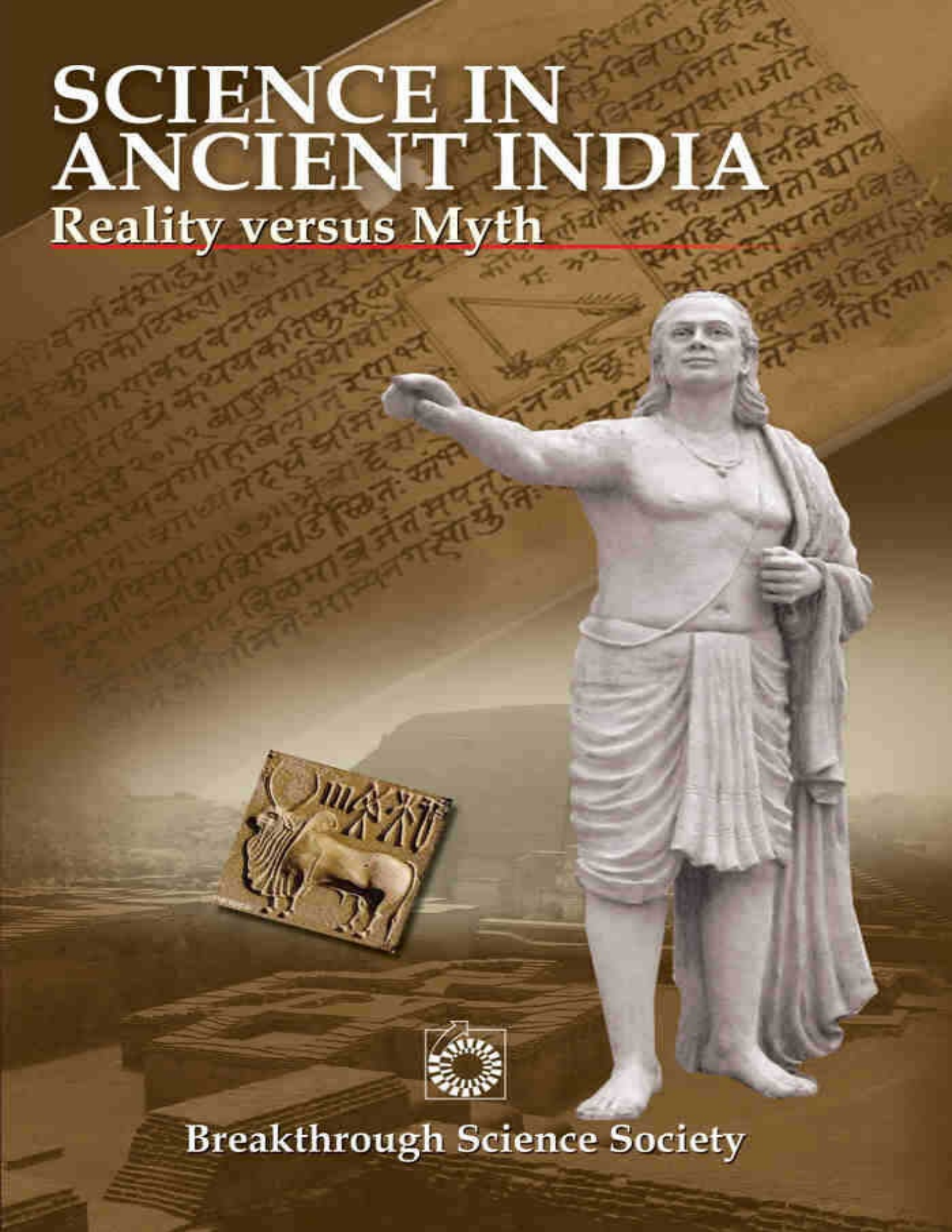
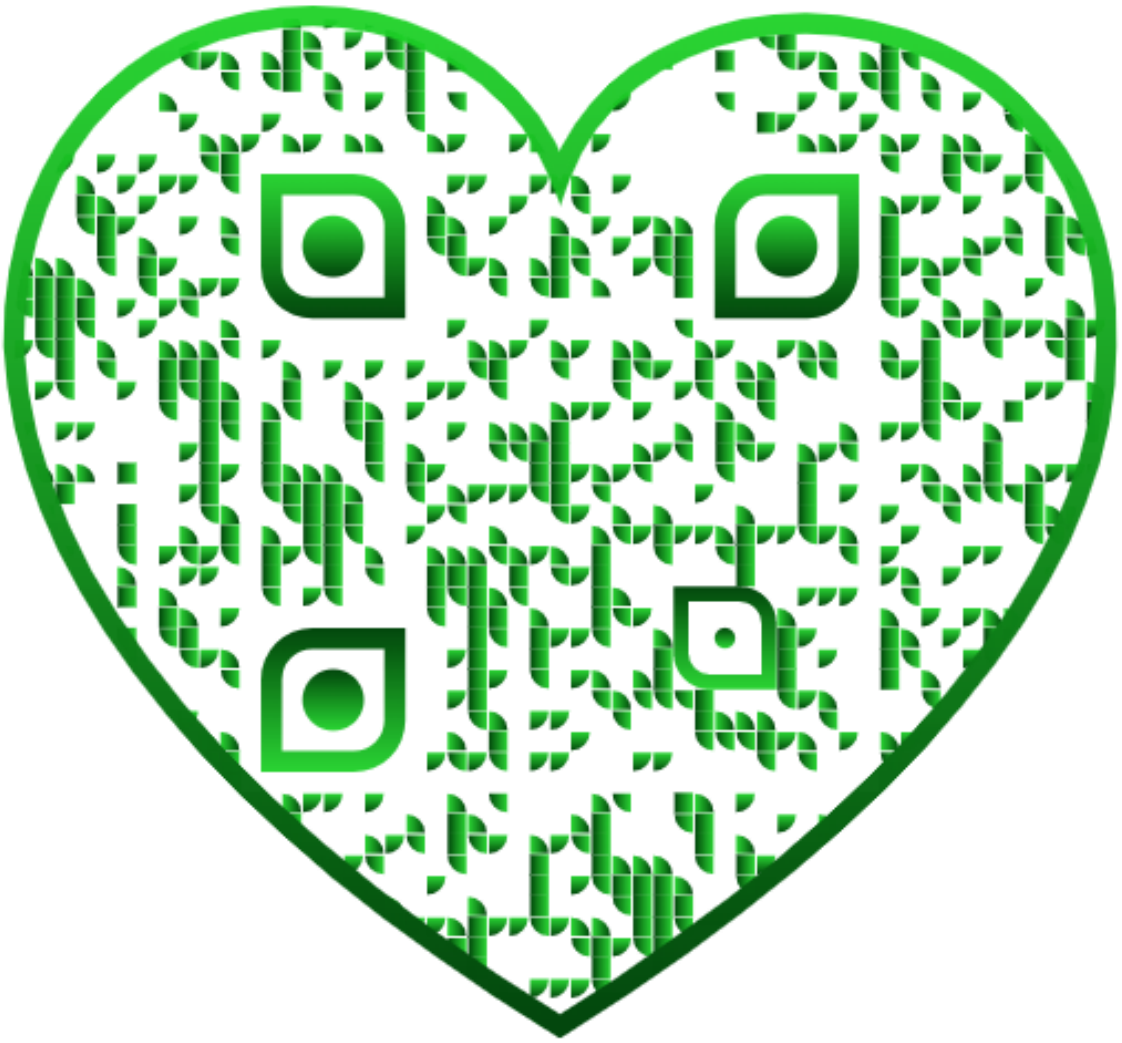
SCIENCE IN ANCIENT INDIA

Reality versus Myth



Breakthrough Science Society



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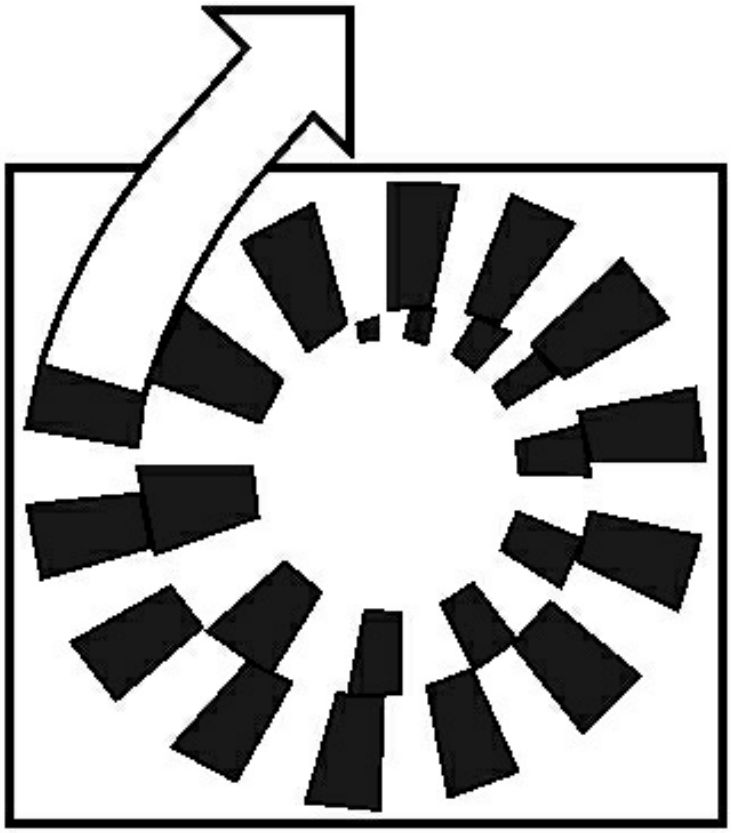

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Preface

The part of the world which is known today as India had a rich scientific tradition in the past. When we study the relics of the ancient times -- from the pre-Vedic Indus Valley civilization, through the Vedic age and to the post-Vedic or Siddhantic period -- we find evidence of this scientific tradition. This land witnessed a gradual enrichment of human knowledge about nature and the natural processes, each generation building on the knowledge acquired by the earlier ones. In certain periods, the social conditions and the prevalent philosophical outlook accelerated the pace of development of science in this land, and in some other times it retarded the process.

Yet, instead of being proud of this scientific heritage and building on it, we are witnessing a disturbingly growing trend. The spread of unscientific beliefs is on the rise and ludicrous claims are being made about the achievements in of science in ancient India. In particular, a fanciful picture of the Vedic period is being painted with the express view to foment obscurantism and religious jingoism, which, if successful, will strike the death knell of the development of a scientific culture in India.

In this booklet we intend to do a thorough reality check. What were the real contributions of this land in science? We approach this question with an unprejudiced mind, and rely only on dependable and objective evidence to piece together the achievements in different areas of science and technology, in different periods of our history. We also examine the credibility of the various myths being deliberately created and circulated by passing off mythology as history.

We hope that this booklet will contribute to creating scientific and secular ethos in the country, left to us by the great personalities of the Renaissance and the Indian freedom struggle.

The first print of the booklet was very well received by inquisitive readers and was exhausted within three months. The booklet is now going into the second print.

May 2016 Dhruba Mukhopadhyay

Kolkata, President,

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Chapter 1

Introduction

In recent times certain claims are being made about the achievements of science in ancient India, due to which it has become necessary to understand the rich heritage of science in ancient India in its proper historical perspective, to be able to do a reality check.

The Indian Science Congress 2015 was held in Mumbai from 3rd to 7th January. There was a scheduled session titled "Ancient Science Through Sanskrit" in which a principal of an aviation school, Mr. Anand Bodas, claimed that the Vedic *rishis* had developed aviation technology to such heights that their flying machines could move forward, backward, to the left, and to the right at great speeds and could y not only to other continents, but even to other planets! As per newspaper reports, former Uttarakhand Chief Minister and BJP MP Ramesh Pokhriyal has claimed that modern science was a pygmy when compared to astrology developed in ancient India. The Prime Minister himself has claimed, while inaugurating the H N Reliance Foundation Hospital in Mumbai on 28 October 2014, that Lord Ganesha was proof of the fact that the ancient rishis practised surgery at such a level that they could implant the head of an elephant on the torso of a man; that the birth of Karna is a testimony to the fact that the ancient sages had knowledge of test-tube baby technique! Such opinions coming from the highest seats of power cannot be brushed aside, because these become official creed.

It is anticipated that there will be two types of reaction to this. One group will claim even more vociferously that the stories in the Puranas, Upanishadas, Ramayana and Mahabharata were actual historical facts; that giants like *Kumbhakarna* and *Ghatotkacha* actually did exist due to the developments in genetic engineering; that *Hanuman* actually flew with a mountain on his shoulder - due to the developments in aeronautical engineering, ad infinitum. Such utterances will only make the Indian scientific community laughing stock before the world and will erode the credibility of the genuine contributions of ancient India. On the other hand, some people will seek to undermine the genuine Indian contributions to the world of knowledge and will claim that all developments happened in the West. Both trends of thought are wrong and harmful.

In this situation one needs to know the true contributions of India - things that we can rightfully be proud of. At the same time we should learn to distinguish truth

from myth and (deliberate) falsehood. The purpose of this book is to apprise the reader about these aspects related to Indian history.

1.1 Is there a scientific method of understanding history?

Unfortunately our education system teaches history as a collection of facts about what happened in the past, full of dates and names, without showing the causal link between the political events and the economic and cultural status of the time. It teaches history as a chronological account of kings' ascent to power, conflicts between kings and kingdoms, the rise and fall of empires, and the gallantry and heroics of kings and their generals. As a result, most students abhor the subject of history because it demands them to memorise dates and names.

More importantly, textbooks of history do not tell students how we came to know about events that happened in the distant past. Is there any scientific way of finding out what happened in the past? In the absence of such an exposition about the scientific method of studying history, people tend to believe whatever is fed to them as elements of history.

In fact, in some sense writing of history- historiography as it is called - is also a science. That is because one has to follow a strict scientific procedure in discovering what happened in the past. One cannot depend on one's personal beliefs and fancy. Science always demands evidence. And the evidence in the hands of the historian comes in two forms: monuments and documents. The objects one finds through archaeological excavations - the buildings, temples, and the objects of daily use, like tools, weapons, dresses and pottery - are the monuments. And the written material - be it in the form of literature, seals, or even a statement of accounts showing the income and expenditure - are the documents. The historian has the task of piecing together the jigsaw puzzle of history on the basis of such evidence.

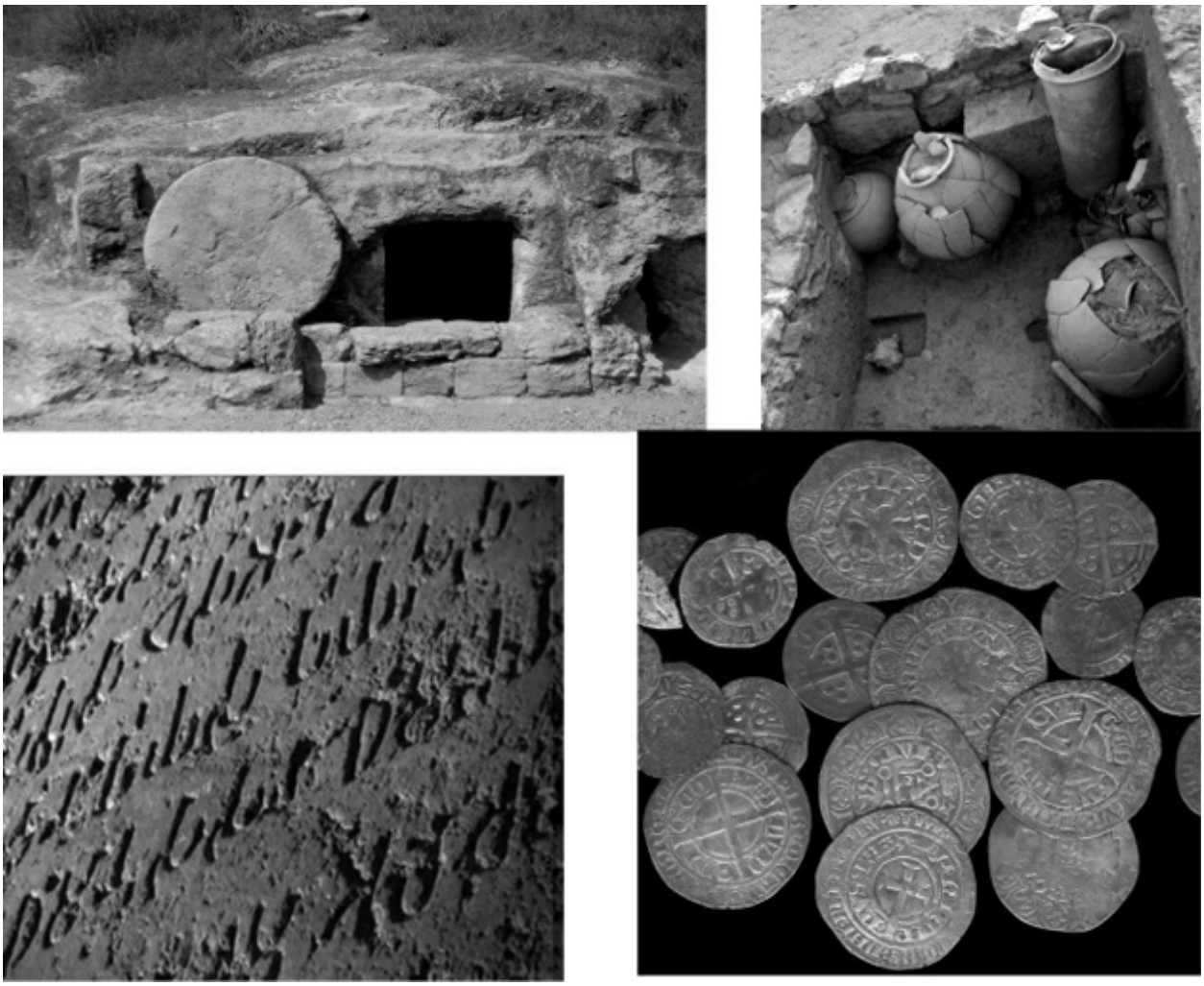

Figure 1.1: Some examples of monuments and documents - what constitutes "evidence" in historiography.

That is why historiography cannot and does not depend on what one believes or imagines about the events in the past. One has to produce evidence in support of any account of history. That is why we have to demand evidence whenever something is claimed to be an element of history.

History of India is generally divided into five phases [1] :

- Indus Valley civilization (3500 BC to 1800 BC)
- Vedic age (1500 BC to 600 BC)
- Post-Vedic period (600 BC to 1100 AD)
- Medieval period (1100 AD to 1850 AD)

- Modern age (1850 AD to present)

On what basis are these time periods identified? The Indus valley civilization is dated on the basis of the objects found in the archaeological sites and their radiocarbon dating. As we shall see, we do not have much archaeological evidence of the Vedic period, and so we have to depend on the literature dating from the Vedic times. The end of the Vedic period is identified with the advent of the Jain and Buddhist religions and much of India adopting these religions. The post Vedic period is a time of remarkable advancements in science and mathematics as evidenced by the writings of legendary figures like Aryabhata, Brahmagupta, Bhaskara II etc. The onset of the medieval period is identified with the decline and fall of the scientific tradition of India. And the modern age marks the onset of the Indian Renaissance heralded by Rammohan and Vidyasagar, after which we see the emergence of a large number of Indian scientists - J C Bose, P C Ray, C V Raman, S Ramanujan, M N Saha, S N Bose, and a host of others.

In understanding the rich scientific heritage of India, let us start with the the Indus Valley civilization.

Chapter 2

The Indus Valley Civilization

The ancient civilization discovered by excavations in Harappa, Mahenjo-Daro, Dholavira, Lothal, and about a hundred other sites in Western India and Pakistan was, in the opinion of many experts, the most advanced civilization of the Bronze Age. Radiocarbon dating has revealed that this civilization, also known as the Indus Valley civilization, existed from about 3500 BC to about 1800 BC, out of which the period from 2800 BC to 2500 BC was the time of maximum development.

Archaeologists were particularly surprised to see the planned layouts of these ancient cities. Roads, 9 feet to 34 feet wide, brick houses built over square and rectangular plots of land, large granaries, public baths, street lighting - all these indicate that civil engineering, town planning, and architecture were quite advanced in this civilization. There are many remarkable items of civil engineering, such as, drainage systems for water (open and closed), irrigation systems, river dams, water storage tanks carved out of rock, moats, homes with private bathrooms and drainage, multiple-storied buildings with stairs, and even a dockyard.

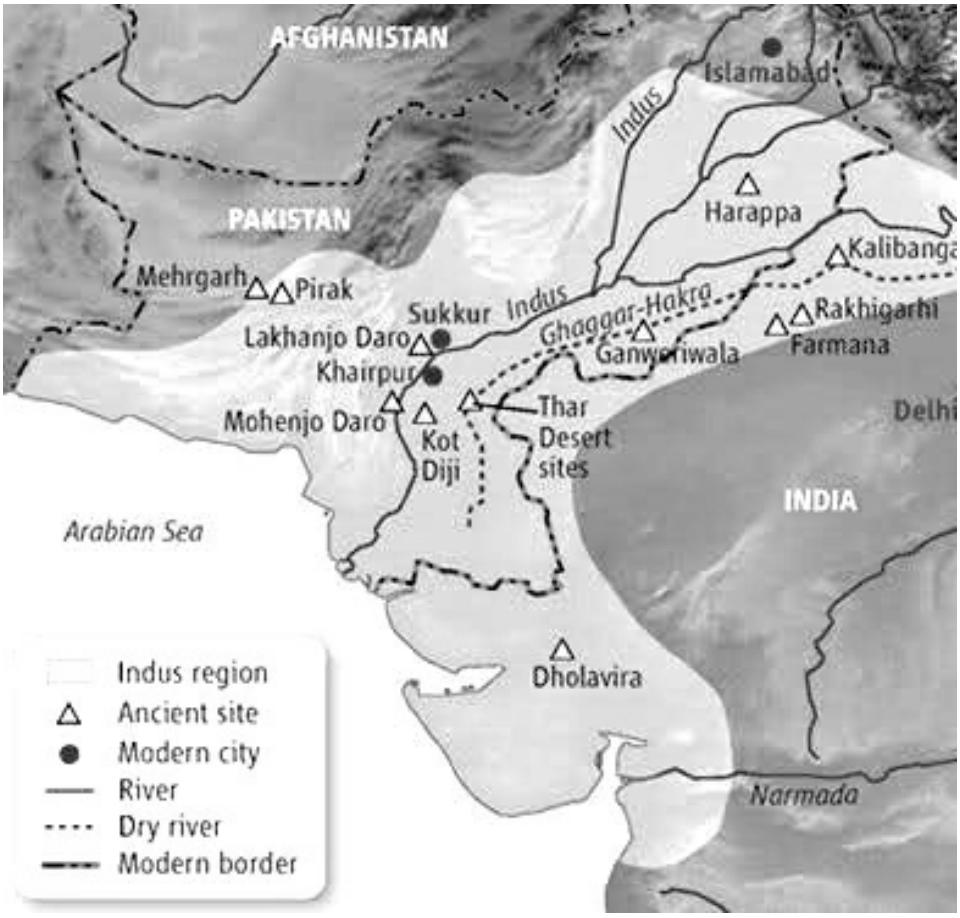

Figure 2.1: Locations of some of the major sites of the Indus Valley civilization.

These cities are characterized by a citadel or raised area. In Mohenjo-Daro, the citadel is built on an architectural platform about 45 feet above the plain. On the summit was a granary where food used to be stored for protection from possible floods. Close to it was a communal bath. Most private houses had their own wells, bathing spaces, and toilets consisting of brick seats over a drainage area. Brick-lined drains flushed by water carried liquid and solid waste to sumps, and then carted away, probably to fertilize nearby fields. The town plan was regular. The regularity of plan and construction suggests some form of government with organization and bureaucratic capacity. But in these cities we find no monumental architecture. The absence of large palaces or temples indicates an early stage of class division.

Such architecture requires knowledge of geometry, especially the construction of squares, rectangles, and rectangular parallelepipeds. The Indus Valley people designed a ruler (called the Mahenjo-daro ruler) that was divided into ten equal

parts. All bricks had the ratio 1:2:4, regardless of their size and location. The seals also show intricate geometric patterns. It was an agriculture-based society. But the artefacts discovered in these sites also indicate significant advancement in textiles, pottery, and metallurgy (copper and brass).

Figure 2.2: Picture of the Mohenjo-Daro ruins, with the great public bath in the foreground.

Archaeological evidence indicates that by about 1700 BC, the Harappan civilization was on the verge of decline. The causes of its decline are not certain. Climatic changes and long spells of drought (or flooding) may have led to the decline in agriculture. The increase in population and the decrease in agricultural output may have created economic problems leading to a gradual decay of culture. A concentrated population is also subject to risk of infectious diseases like plague. The physical existence of the civilization possibly ended when the inhabitants were forced to abandon the cities to move to other areas with better prospects of

livelihood. Such decline and extinction of a culture are not uncommon in ancient civilizations; Inca and Maya civilizations of South America offer similar examples.

Chapter 3

The Vedic Age

Some tribes speaking Proto-Indo-Iranian languages migrated from Asia Minor into West Asia and Europe from around 2500 BC and a few influxes occurred into North-Western India sometime between 1800 BC and 1500 BC. These were horse-riding pastoral migratory tribes whose livelihood came mainly from animal husbandry. They did not create urban civilizations like Harappa and Mahenjo-Daro (cities grew in Aryan-speaking land only after 600 BC); they did not have a written script; they were also significantly backward in terms of science and technology in comparison to the people in the Indus valley civilization. But they settled in the Indian subcontinent, and slowly gave birth to a very rich culture that was to have tremendous impact on the history of the subcontinent.

The thousand year span from the migration of the Aryan-speaking people till the onset of the Buddhist era (approximately from 1500 BC to 600 BC) is called the Vedic age. No material object that could enable dating has been found from the Vedic times - no houses, no tools, no weapons, nothing. The Vedas, Vedanga, Vedanta, Puranas, Upanishadas, Brahmanas and Samhitas were the intellectual creations of the time. In absence of any material object that facilitates dating and assessment of cultural progress, these literatures serve as the only source for objective assessment of the culture and its scientific development.

3.1 Mathematics in the Vedic Age

It is to be noted that in the initial phase of the Vedic period there was no written language. Vedas and other literature were propagated from one generation to another through oral tradition - through sruti (to listen) and smriti (to memorize). But in the late Vedic period (approximately 1000 BC onwards) written script developed, and documents were written down. From these documents we see that the late Vedic people wrote numbers in a system that had nine basic number-symbols. Zero had not been discovered and the place-value system had not been invented at that time. So, to write 10 they needed a new symbol. Then they could proceed to write 11, 12, etc., by putting the basic number symbols after the symbol for 10. But they again needed a new symbol for 20. That way, they needed new symbols for 10, 20, 30, $\cdots$ 100, 1000, etc. We see the same system of writing numbers all the way to Ashoka's time - the Brahmi and Kharosti scripts of the stone

tablets also use the same method of writing numbers.

In the Vedic literature we also find names for the higher powers of 10. Historians are surprised by the fact that they could conceive large numbers in spite of the handicap of not being able to write such numbers. For example, we see mention of the powers of ten up to a trillion in *Krishna Yajurveda* . In the *Taittiriya Samhita* we see mention of arithmetic progression and geometric progression. They could add, subtract, multiply and divide simple fractions (for example, we see it stated in the *Purusha Sukta* : when three-fourths Purusa went up, one-fourth of him remained). We also see attempts to find the square root of 2 and 3 in terms of continued fractions. Rudimentary concepts of geometry can be found in *Satapatha Brahmana* and *Taittiriya Samhita* (900BC).

But the most impressive development in geometry can be found in the *Shulvasutras* . The Shulvasutras are a collection of texts written between 800 BC and 200 BC, so these could be said to belong to the late Vedic and early Buddhist periods. There are seven Shulvasutras:

1. Boudhayana Shulvasutra
2. Apastamba Shulvasutra
3. Katyayana Shulvasutra
4. Manava Shulvasutra
5. Maitrayana Shulvasutra
6. Varaha Shulvasutra
7. Vadhula Shulvasutra

These are basically the laws of measurement with the aid of a rope (shulva-sutra literally means "rules of the cord"), much of it meant for erecting sacrificial altars. The oldest sutra attributed to Baudhayana is thought to be composed between 800-600 B.C.

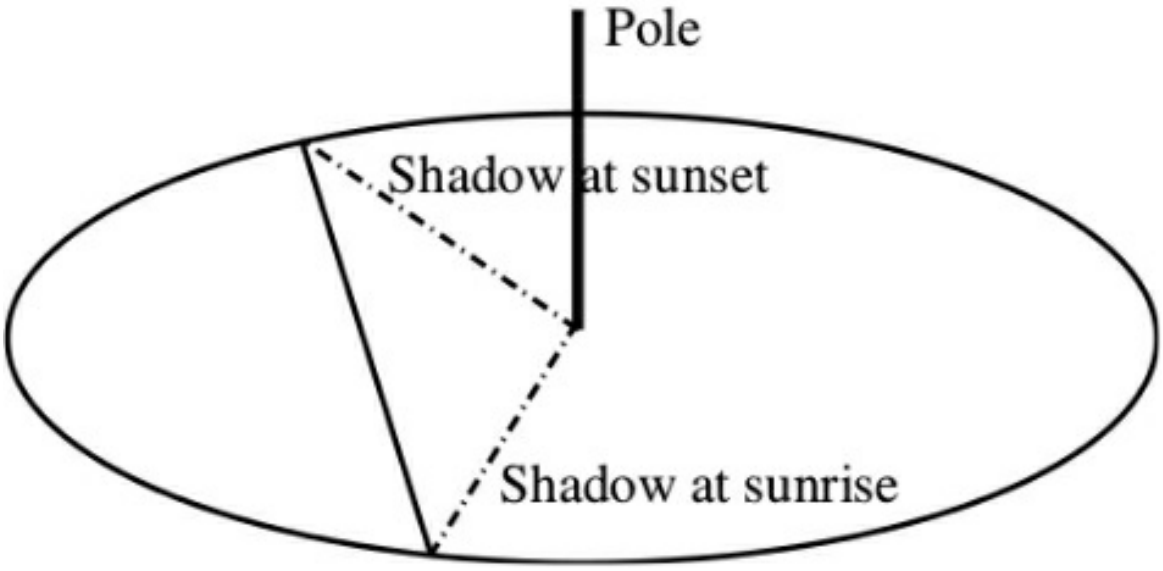

Figure 3.1: Method of identifying the East-West line according to *Shulvasutra* . Put a vertical pole on the ground. Draw a circle around the pole with the help of a rope. Now, at sunrise observe the shadow of the pole and mark the point where the shadow intersects the circle. Do the same procedure at the sunset. Join the two points on the circle obtained this way. This is the true East-West line at that spot.

In order to prepare an elevated *yagna-vedi* , how would you proceed? You have to start by deciding the orientation, and the Vedic tradition demanded that the sides should be aligned along the North-South-East-West directions. Thus, the first step is to find out these directions at a given place. But it is not an easy problem, because you cannot identify the North-South direction without a magnetic compass. Even though the sun rises in the East and sets in the West, the directions of sunrise and sunset are not truly to the East and West and changes with time of the year. Still, the *Shulvasutras* recommend starting by identifying the East-West line, called *Praci* . Their method is shown in Fig. 3.1 . It actually identifies the correct east-West direction.

In order to draw a square or a rectangle, you have to draw a perpendicular line. How can you do that just by using a rope? The *Shulvasutra* method is shown in Fig. 3.2 .

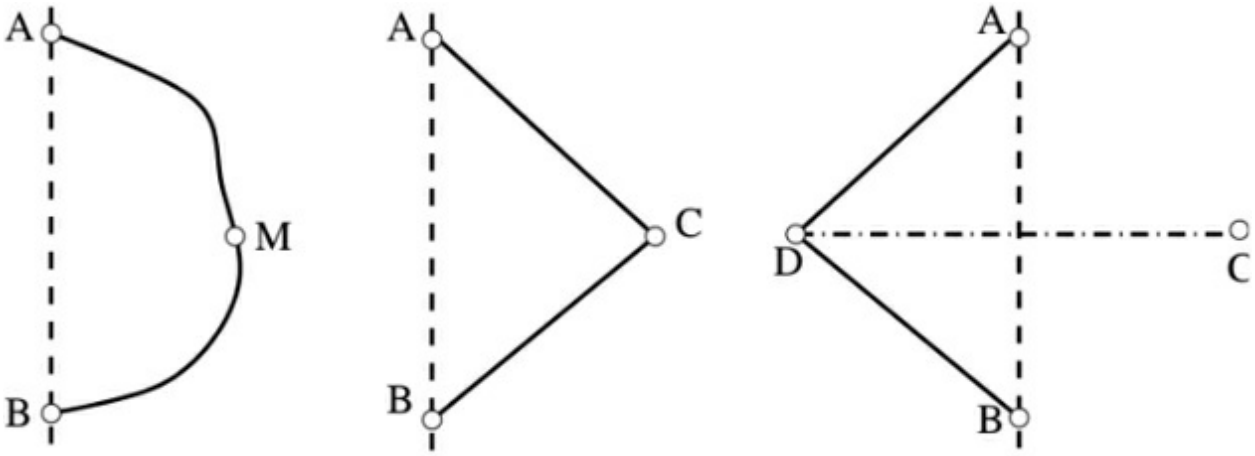

Figure 3.2: The method of drawing a perpendicular bisector using a rope. Take two points A and B on a line, and take a rope longer than the distance between the two points. Mark the mid-point M of the rope by folding it in half. Now hold the two ends of the rope at the two points on the line, and stretch it in one direction. Mark the point C where the mid-point lies. Now stretch the rope in the other side and do the same thing. You get two points C and D, and the line joining them is the perpendicular bisector.

They had to solve a few more intricate problems of geometry to tackle the construction of raised platform or *vedi* used in *yagnas* . For example, they had to construct altars of different geometrical shapes of the same area for each god. The *Shulvasutras* gave methods of geometric area-preserving transformations from one geometric shape to another, such as from a square to a circle and vice versa, from a square to an isosceles triangle, to a rhombus etc. Their method of circling a square is shown in Fig. 3.3 [2] .

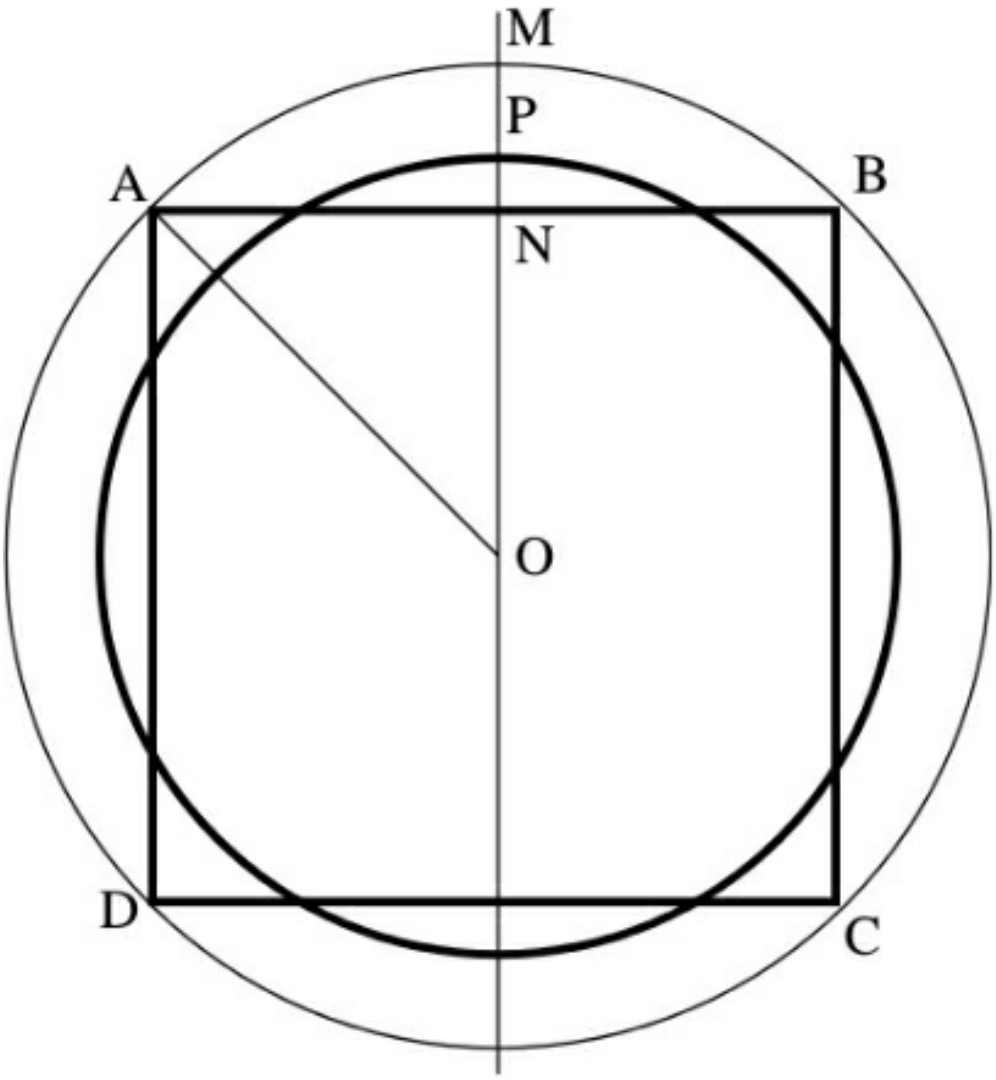

Figure 3.3: Circling the square. Let ABCD be the given square, with center at O. Join OA. Draw a circle centered at O with radius OA. Find the point of intersection M with the line through O perpendicular to AB. Find P on MN such that MP 2PN. The circle being sought is the one with center at O and radius OP.

We also find in *Boudhayana Shulvashutra* a method of the inverse transformation: obtaining a square of the same area as a given circle. "If you wish to square a circle, divide its diameter into eight parts; then divide one part into twenty-nine parts and leave out twenty-eight of these; and also the sixth part (of the preceding sub-division) less the eighth part (of the last)." According to this prescription, the side of the square will be

$$a = \frac{7d}{8} + \frac{d}{8}\left(1 - \frac{28}{29} + \frac{1}{29}\left\{\frac{1}{6}\left[1 - \frac{1}{8}\right]\right\}\right)$$

This gives a= 0.87868d. Now we know that the area of the square is a^2 and that of the circle is $\pi d^2/4$. Thus, as per modern calculation, the value of a should be $\sqrt{\pi}$ d/2 = 0.886228d and thus their prescription was reasonably good.

How long would be the sides of a square if the area were to be whole numbers like 1, 2, and 3? Thus they faced the problem of obtaining the square root of these numbers. We find in *Baudhayana Shulvasutra* a *shloka* which, when translated to a mathematical expression, reads as

$$\sqrt{2} = 1 + \frac{1}{3} + \frac{1}{3 \times 4} - \frac{1}{3 \times 4 \times 34}$$

This gives a value of 577/408 = 1.4142156 while the correct value of $\sqrt{2}$ is 1.414213, that is, the value obtained by *Boudhayana* is accurate to five decimal places!

There is also indication that the theorem known by the name of Pythagoras was known to the writers of the Shulvasutras. *Baudhayana* gave the following general statements of the Pythagoras theorem: "A rope stretched along the length of the diagonal produces an area which the vertical and horizontal sides make together" and "For a rectangle the squares produced by the length and breadth together equal the area produced by the diagonal." He also gave sets of numbers like (3, 4, 5), (5, 12, 13), (8, 15, 17), (7, 24, 25), and (12, 35, 37) which form "Pythagorean triplets" - sets of three integers that follow the rule $x^2 + y^2 = z^2$. But no proof was given.

This raises the question: Who, really, discovered the Pythagoras theorem? Prof. Manjul Bhargava, the famous Fields Medal winning mathematician of the Princeton University, says that the answer to the question depends on how you look at it! The Egyptians who constructed the Pyramids must have had some idea about it. The first to mention the Pythagorean triplets were the Mesopotamians, as far back as 1800 BC. The first formulation of the statement of the theorem is found in the *Shulvasutra* . The Chinese were the first to provide a proof (500 BC). Pythagoras' own contribution was probably to present a rigorous mathematical statement and proof in the 6th century BC. Euclid mentioned it in his treatise on geometry, from which the theorem has come to be known as the Pythagoras theorem.

These were real and commendable developments in mathematics. As we shall

see later, these real developments have no link with what is claimed to be "Vedic Mathematics", which is being introduced in the school curriculum in some states.

3.2 Vedic Astronomy

In the late Vedic period, agriculture was started in addition to animal husbandry, and a calendar had to be formulated in order to fix the timings of sowing, reaping, and other agricultural activities. That provided the primary motivation for studying the motion of the objects in the sky. In addition, fixing of the times of holy events like the performance of a yagna also induced people to look for auspicious events in the sky.

The Vedic literature show that they counted months on the basis of the phases of the moon, and the year on the basis of the motion of the sun. Since a whole number of moon-months do not make a sun-year, the extra days were counted as "*mal-mas* ", a period when no auspicious event could be held. The year was divided into two parts: when the sun moved towards the North (*Uttarayana*), and when the sun moved towards the South (*Dakshinayana*), and they could identify the summer and winter solstices. In *Yajurvdeda* , a year comprising 12 solar months and 6 *ritus* (seasons) was recognised. The six *ritus* , in the Vedic nomenclature, are *Vasantaritu, Grishmaritu, Varsharitu, Sarathritu, Hemantaritu* and *Sisiraritu* . In addition they named 27 stars along the path of the sun and the moon, and could specify the positions of the sun and the moon in the background of these stars. There is mention of the planets Jupiter and Venus.

It is important to note that in the Vedic period there was no astrology - in the sense of beliefs in human lives being predestined by the time of birth and the influence of planets on human lives. The word *Jyotisha* was used in the sense of astronomy.

3.3 Medical science in the Vedic Age

Remarkable developments happened in medical science during the late Vedic period. The *Atharva-Veda* contains many ideas about anatomy, physiology, and medicines which, though not quite correct in the light of modern science, were much advanced when compared to the knowledge of the other societies of the same period. We see the mention of many diseases like fever (the symptoms indicate that this was malaria), indigestion, cough and cold, tuberculosis, leprosy, headache, tumour, etc. However, some erroneous ideas also orginitated at the time of the

Atharva-Veda . For example, it was believed that all diseases are caused by malfunction of three "*doshas* ": *Vata, Pitta, and Kapha* . It was believed that these malfunctions happen due to the attack of *bhutas* or ghosts. So it recommended various *mantras* , ritualistic practices, and wearing of hand-bands (*kabachas*) to drive away the evil spirits. At the same time the *Atharva-Veda* also mentions the use of certain plant-derived products to treat patients of the above diseases.

It seems different schools of thought regarding the methods of treatment existed at that time. Some recommended occult practices to drive away evil spirits while some others recommended the use of different plant leaves, roots, seeds, bark and similar materials. Those who practised the use of plant-derived materials were called *Bhishak* . Slowly the second school gained prominence and in their writings we find the mention of many medicinal plants.

The *Ayurveda* was written in the late Vedic period and the early Buddhist period in continuation of this tradition. Some people feel that *Ayurveda* is a part of the *Atharva Veda* , while some others place it in the position of a separate Vedadue to the noticeable shift in emphasis.

It is divided in eight chapters: medicine, surgery, treatment of eye, ear, nose, and throat diseases, treatment of psychological problems, treatment of children, poisons and their effects, chemistry and preparation of medicines, and treatment of sexual diseases. Such attempt to systematize the empirical knowledge of that period is undoubtedly praiseworthy.

In the next chapter we'll see that this tradition reached a very high level in the hands of eminent physicians like Susruta, Charaka, Jivaka, Atreya, etc., in the post-Vedic period.

3.4 Philosophical content of the Vedic Age

What was the content of the Vedas? These are mainly chants, hymns, and methods of worship in praise of the gods and asking for material benets in return. The gods of that period were actually embodiments of natural forces (*Agni, Varuna, Surya,* etc.) or deification of some Aryan leader (like *Indra*) successful in defeating the non-Aryans. That is why historians opine that the essential content of the thought process of men in *Rigvedic* times was materialistic (that is, based on material entities and objects). That is why the *Rigvedic* hymns reflect a healthy curiosity about nature and natural phenomena, which was conducive to development of scientific enquiry. Such cultural phase has been observed in all societies in the past - a period that the

anthropologists term as the "magic phase". It is only towards the end of the Vedas (i.e., *Vedanta*), when we see spiritual content entering the cultural landscape.

Many people carry a misconception that spiritualism is the only characteristic feature of the Vedic times. Actually many different philosophical currents were very much alive during this period. One of these philosophical currents is called *Lokayata* (sometimes also called *Charvaka*). It did not believe in the existence of *atma* or soul, refused to accept anything on the basis of belief, and theorized that everything in the world is made of four constituents or *chaturbhuta* : earth, water, air, and fire (a fifth one, sky, was added later). It believed that when a man dies, his body returns to these four constituents, and does not go to heaven or hell. Whether the ideas like *chaturbhuta* were correct in the light of modern science is not of our concern. What really matters is the fact that it sought to explain the world through material processes and phenomena. Other philosophical lines of thought like *Nyaya-Vaiseshika* and *Samkhya* also existed. Notwithstanding the differences between these lines of thought, at the basic level they were also materialistic philosophies. Under the influence of these philosophical currents, there was a healthy curiosity about the material world, and we see steady progress in man's understanding of it.

But the later Vedas laid too much emphasis on ritualistic practices like *yagnas, homas* , chants, and on prescribing what to do and what not to do. Such an environment hampered the natural enquiring mind of men, and so the scientific enquiries subsided. With the "end" of Vedas when *Vedanta* came, it sought to create an alienation of the individual from the material world. Seeking *nirvana* away from life and society became the ideal for the learned people. This created a condition detrimental to the growth of scientific enquiry.

3.5 The claims regarding the Indus and Vedic cultures

In recent times various claims are being made - mainly by the fringe groups - by mixing science with mysticism, and history with mythology, in order to create an imaginary picture of India's past glory based on religious chauvinism. The claims are

1. The Indus Valley civilization was a part of Vedic culture
2. There was no Aryan migration into India; Aryans were indigenous people of India and the Vedic culture is more than 10,000 years old.
3. Students of modern age should learn Vedic mathematics. A book on this subject is being introduced into the school curriculum in some states.

In the following sections, we shall briey deal with these, to enable the readers to judge for themselves the veracity of these claims.

Claim 1: Indus Valley civilization was a part of the Vedic era

On this issue, we need to understand why, soon after the discovery of the Harappan sites, historians and archaeologists had come to the conclusion that this was a pre-Vedic civilization. They had found five important clues.

1. The Harappan people knew how to make bricks, but the Vedic people did not. Not a single brick has been found in the one thousand year span of the Vedic age. It is now believed that the Vedic Aryans lived in houses built of wood, bamboo and reeds. After the Indus Valley civilization, the first brick-built building was found in the Buddhist period, during the reign of the Maurya dynasty. Even in Ashoka's time (3rd century BC), structures were made of stone and timber. The first brick has been found in a temple in Bhitargaon, UP, dating around 6th century AD.

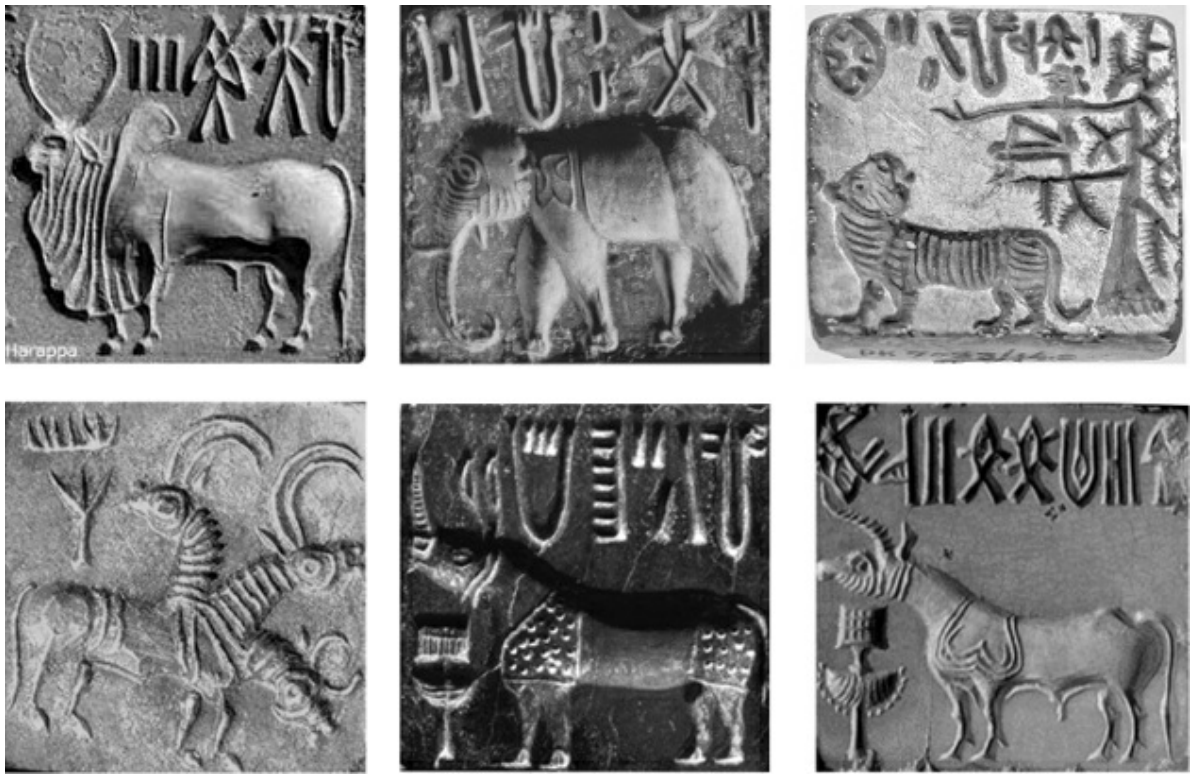

Figure 3.4: A few representative seals found in the Indus Valley sites.

2. The horse is the main animal in Vedic literature. But no skeletal remains of the

horse has been found in any of the Indus Valley cities. The main animal depicted in Indus Valley art, sculpture and seals, is the bull. Fig. 3.4 shows the pictures of a few seals from the Harappan sites depicting various animals (bull, elephant, tiger, rhinoceros and even imaginary animals - one a deer with three heads, and another named the unicorn, with a bull's body, deer's head and one long horn). Not a single picture of a horse has been found. This implies that this animal - the horse - was not known to the Harappan people, but was very common in the Vedic age.

3. The Harappan people had a written language, examples of which can be seen on the seals in Fig. 3.4 . Scientists have not succeeded in deciphering the script because it has no resemblance with any of the modern languages. In contrast, the Vedic people did not have a written language in the early part of the Vedic age. That is why the *Rigveda* was communicated through *sruti* (to listen) and *smriti* (to memorize), and was written up much later.
4. No description of the Harappan cities are found anywhere in the literature of the Vedic age. There are no references to structures built on platforms, or the grid pattern of streets and the careful construction of drainage systems, to granaries, warehouses and areas of intensive craft production, to seals and their function, etc. "If the two societies were identical", writes the eminent historian Romila Thapar, "the two systems would at least have to be similar."
5. The pantheon (gods and goddesses) are also dierent in the two civilizations. Note that, even though Shiva was a non-Aryan god, there is no evidence of Shiva worship in Indus Valley cities. It may have entered the Vedic pantheon through interactions with other regions of India.

There have been attempts by the fringe groups to contradict these pointers. In the year 2000 a book titled "The Deciphered Indus Script" was published by N. S. Rajaram and N. Jha which claimed that the authors had succeeded in reading the scripts and that these are actually worship of river Saraswati, in Sanskrit. They also claimed to have found the image of a horse in a Harappan seal. The claims were soon debunked by archaeologists who showed that the translation was a complete figment of the imagination. There are linguistic rules that have to be observed in any decipherment, which make it necessary for a claim to stand the test of linguistic analyses. No such scientific process was followed in the claim of Rajaram and Jha. Moreover, to claim the discovery of "horse seal" in Harappa, a broken seal was photographed by shining light from one side so that the shadow looks like the image of a horse. For details the reader may refer to the article by the Harvard Indologist, Michael Witzel, and historian, Steve Farmer, in Frontline (September 30, 2000).

Figure 3.5: The so-called *Pashupati* seal.

Sometimes a particular seal, called the "*Pashupati* seal" is cited in support of the belief that Shiva worship was prevalent in the Indus cities. Fig. 3.5 shows a picture of this seal. The fact is that the name did not come from antiquity. The archaeologist John Marshall, the then Director of the Archaeological Survey of India, named it the *Pashupati* seal (meaning: master of animals) because the central figure is surrounded by animals. But, calling the central figure with a horned headgear as a

"proto-Shiva" would be over-exercising the imagination.

Claim 2: Vedic Aryans were original residents of India

Today Hindutva theorists are claiming that the Aryans did not come from outside the land. Some of them change the antiquity of the Vedic culture - some say it is 10000 years old, some say 50000 years. That is why it is necessary to understand on what basis the scientists have come to the conclusion about the antiquity of the Vedic age.

The first evidence is linguistic: It has been found that the languages spoken in Europe and in India have a common root. This is because many words are similar, or have common origins. It is known that pronunciation of the same word changes as one goes from one region to another. But linguists are able to find the similarity of the words in spite of the difference in pronunciation. Table 3.1 shows a few such words that have common origins.

Similarity in words between the Indian and European languages.

English	Greek	Latin	Sanskrit
brother	phrater	frater	bhrata
father	pater	pater	pita
foot	poda	pedem	pada
three	tris	tres	tri

Moreover, there are similarities in grammar also. Take the example of case (*karaka*) of the Indian languages. It is found that Sanskrit had the most cases (8), followed by Old Church Slavonic, Lithuanian, and Old Armenian (7), Latin (6), Greek, Old Irish, Albanian (5), Germanic (4). Thus, case is a common feature of the Indo-European language family. Similarly, we find three genders (masculine, feminine, neuter) in a number of Indo-European languages, and the common feature that the form of the verb changes according to the gender. It is also found that the three numbers (singular, dual, plural) survived in Sanskrit, Greek, and Old Irish. Vestiges of the dual number can be found in many other Indo-European languages.

That is why these languages are classified under a group, called the Indo-European family of languages. The proto-Indo-European language is believed to have branched into two major groups, now called the Centum languages and the Satem languages - the first one is the mother of all European languages and the second one gave birth to the Indo-Iranian language family to which all North-Indian and Middle-Eastern languages belong. That is why it is believed that the Indo-European language group has radiated along with human migrations, starting from a common birthplace. Linguistic evidence suggests that the Indo-Aryans split off from the Indo-Iranians around 1800-1500 BC. That is why most historians (excepting the fringe groups) believe that a few waves of migration of the Aryan-speaking people occurred in the period from 2000 BC to 1500 BC.

The second evidence is zoological: The horse is the prime animal in all Vedic literature, but this animal is not native to the Indian subcontinent. There is no wild horse in any of the Indian forests. Wild horses are found in Asia Minor. Signs of the existence of horses in large numbers are found in India only after a certain time. That is why scientists have come to the conclusion that the horse-riding Aryans entered India around that time.

Nowadays there are attempts to disprove this theory by showing that there were horse fossils in Harappan sites, but the claims have not gone beyond newspaper articles as professional archaeologists do not find scientific merit in such claims.

But the most important point is that, out of the various classifications on the basis of physical characteristics, 'Aryan' was never identified as a "race". The idea of an "Aryan race" was originated by the German fascists, which has been debunked long since. Scientifically it is a language group, and those who spoke that group of languages are called Aryans.

Claim 3: Vedic Mathematics

Nowadays we see attempts to introduce certain calculation techniques into school curriculum in the name of "Vedic Mathematics". The most important one is a book first published posthumously in the year 1965 by Jagadguru Swami Bharathi Krishna Thirthaji Maharaj of the Puri mutt. It contains 16 mathematical aphorisms (*sutras*). These are given in Table *3.2* .

To cite one example, take the case of the sutra "*Ekadhikena Purvena* ". To find the square of 75 the book asks one to follow a few easy steps:

1. The number preceding the last 5 is multiplied by 1 more than itself. 7 + 1 = 8, 7 x 8 = 56
2. Then write 25 after that.
3. We get 5625. This is the square of 75.

Quick, isn't it? Unfortunately it does not work for 26 or most other numbers. It works only for numbers ending with 5. For other numbers you have to use different methods! Thus, the technique does not really reduce the labour; you have to memorize an enormous number of different procedures, each applicable for special cases. Most importantly, the student does not learn the process of multiplication.

The 16 *sutras* of Vedic mathematics.

Sutra	**Meaning**
1. *Ekadhikina Purvena*	By one more than the previous one
2. *Nikhilam Navatash-caramam Dashatah*	All from 9 and the last from 10
3. *Urdhva-Tiryagbyham*	Vertically and crosswise
4. *Paraavartya Yojayet*	Transpose and adjust
5. *Shunyam Saamyasamuccaye*	When the sum is same, it is zero
6. *(Anurupye) Shunyamanyat*	If one is in ratio, the other is zero
7. *Sankalana- vyava\-kalanabhyam*	By addition and by subtraction
8. *Puranapuranabyham*	By the completion or non-completion
9. *Chalana-Kalanabyham*	Differences and similarities

10. *Yaavadunam*	Whatever the extent of deficiency
11. *Vyashtisamanstih*	Part and whole
12. *Shesanyankena Chara\-mena*	The remainders by the last digit
13. *Sopaantyadvayamantyam*	The ultimate, twice the penultimate
14. *Ekanyunena Purvena*	By one less than the previous one
15. *Gunitasamuchyah*	The product of the sum is equal to the sum of the product
16. *Gunakasamuchyah*	The factors of the sum is equal to the sum of the factors

Where did the author find these sutras? He claimed that "the sutras are from the *Parisista* (Appendix) of the *Atharvaveda* ". He further claimed that the formulae or sutras "apply to each and every part of each and every chapter of each and every branch of mathematics - arithmetic, algebra, geometry, trigonometry, conics, astronomy, and calculus". "After 8 years of concentrated contemplation in forest solitude, I was, at long last, able to recover the long lost keys which alone could unlock the portals thereof."

When Prof. K. S. Shukla, a renowned scholar of ancient Indian mathematics,

tried to locate these sutras in the original sources, he could not find them. Subsequently he met the author in 1950 and asked him about the actual *parishishta* in *AtharvaVeda* . The author replied:"they occurred in my own *Parishishta* and not any other." That makes it clear that the author made up these sutras all by himself. Even the General Editor of the first edition of the book, Prof. V.S. Agrawala, clearly states that the sutras do not appear in the hitherto known *Parishishtas* ; that the style of language of the *sutras* point to their discovery by Shri Swamiji himself; and that the work should be regarded as a new *parishishta* .

Prof. S. G. Dani of IIT Bombay and former chairman of the National Board of Higher Mathematics wrote that "the contents of the Swamiji's book have practically nothing in common with what is known of the mathematics from the Vedic period or even with the subsequent rich tradition of mathematics in India until the advent of the modern era." Tirthaji has liberally interpreted three-word Sanskrit phrases to associate them with arithmetic.

Prof. J. N. Kapur, and eminent mathematician and former Vice Chancellor, Meerut University, writes that "Vedic mathematics is not concerned with those aspects of mathematics which do not depend on computation ··· . It does not teach the process of multiplication."

The reasons to doubt the antiquity of the sutras and their purported meanings are easy to understand. We have seen earlier that in the Vedic times people wrote numbers without the use of zero and the place-value system. Discovery of zero happened much after the Vedic age, in the Buddhist period. The techniques in these Vedic Mathematics books include the use of modern decimal number system, and hence these cannot be Vedic in origin. Many of the sutras employ decimal fractions which were not known in the Vedic period. In fact, decimal notation and a method of converting fractions into decimals were not known till the 17th Century - that is why these are not found even in the works of the later mathematicians like Aryabhata, Varahamihira and Brahmagupta.

It is thus clear that in claiming these as Vedic mathematics, the proponents are basically counting on the fact that the average Indian considers anything written in Sanskrit as 'Vedic'. The way Latin was the common language of academic discourse all over Europe before the advent of modern languages like English, German, etc., in a similar way Sanskrit was the common link language of the educated people of India from antiquity all the way up to the medieval period. That is why anything written in Sanskrit is not 'Vedic'.

The most worrisome aspect of these books on 'Vedic Mathematics' is that most of their content is not obtained from ancient literature at all and are creations of people in the modern times, written in Sanskrit. Sometimes text written in modern times are inserted into ancient literature (Prof. Narlikar calls these as *prakshipta* or inserted [5]), and then the whole *shloka* is cited as pointer to certain calculation technique invented by the Vedic people. Sometimes the texts in the *shlokas* are just cryptic phrases from which any meaning can be extracted. The techniques given in the Vedic mathematics books are at best some shortcuts for number crunching that do not help the young minds to grasp the beauty of mathematical logic at all.

We shall end this section by quoting from the eminent 12th century mathematician Bhaskara II: "It is necessary to speak out truth accurately before those who have implicit faith in tradition. It will be impossible to believe in whatever is said earlier unless every erroneous statement is criticized and condemned."

Chapter 4

Science in the Post-Vedic (or Siddhantic) Period

We see a resurgence of science beginning in the 6th century BC when a group of people, disenchanted by the suffocating intellectual atmosphere dominated by ritualistic practices and commandments of the dos and don'ts, started looking for alternative philosophical ideas. Jainism and Buddhism were born in this period. Even though we mainly hear of these two religions, historians have shown that the materialist philosophical thoughts like *Charvaka, Samkhya* , etc., that were born during the Vedic period found resurgence in this period through man's attempts to find alternate ways to interpret the world. Even Buddha did not believe in the existence of god. The presence of such a rich array of philosophical currents and the clash of ideas created an intellectual atmosphere that aided scientific enquiries. That is why we see a resurgence of science starting from the 6th century BC. But this period can no longer be called the 'Vedic' period.

The materialistic line of thinking was alive in India for a long time. But after the 9th-10th century AD, it was weakened and was not able to act as the driving force for the development of science any longer (we'll talk in detail about it later). And this 1600-year period from 6th century BC to about 10th century AD was a golden age of ancient Indian science. We shall discuss this era with reference to the different areas of human endeavour.

4.1 Medical Science

After Atharvaveda and Ayurveda, medical science reached an altogether dierent dimension since the 6th century BC in the hands of a few eminent medical practitioners like Athreya and Susruta (6th century BC), Jivaka (566-486 BC) and Charaka (time uncertain). The unusual aspect of this development is the practice of surgery which was unequalled in the world before the initiation of modern methods of surgery after the European renaissance. *Susruta Samhita* mentions 121 kinds of surgical instruments (Fig. 4.1 shows some of them), and has detailed instruction on how to run the knife and other instruments on different organs, how to sew the wound with plant-fibre after a surgical procedure, what to do in case of broken bones, etc.

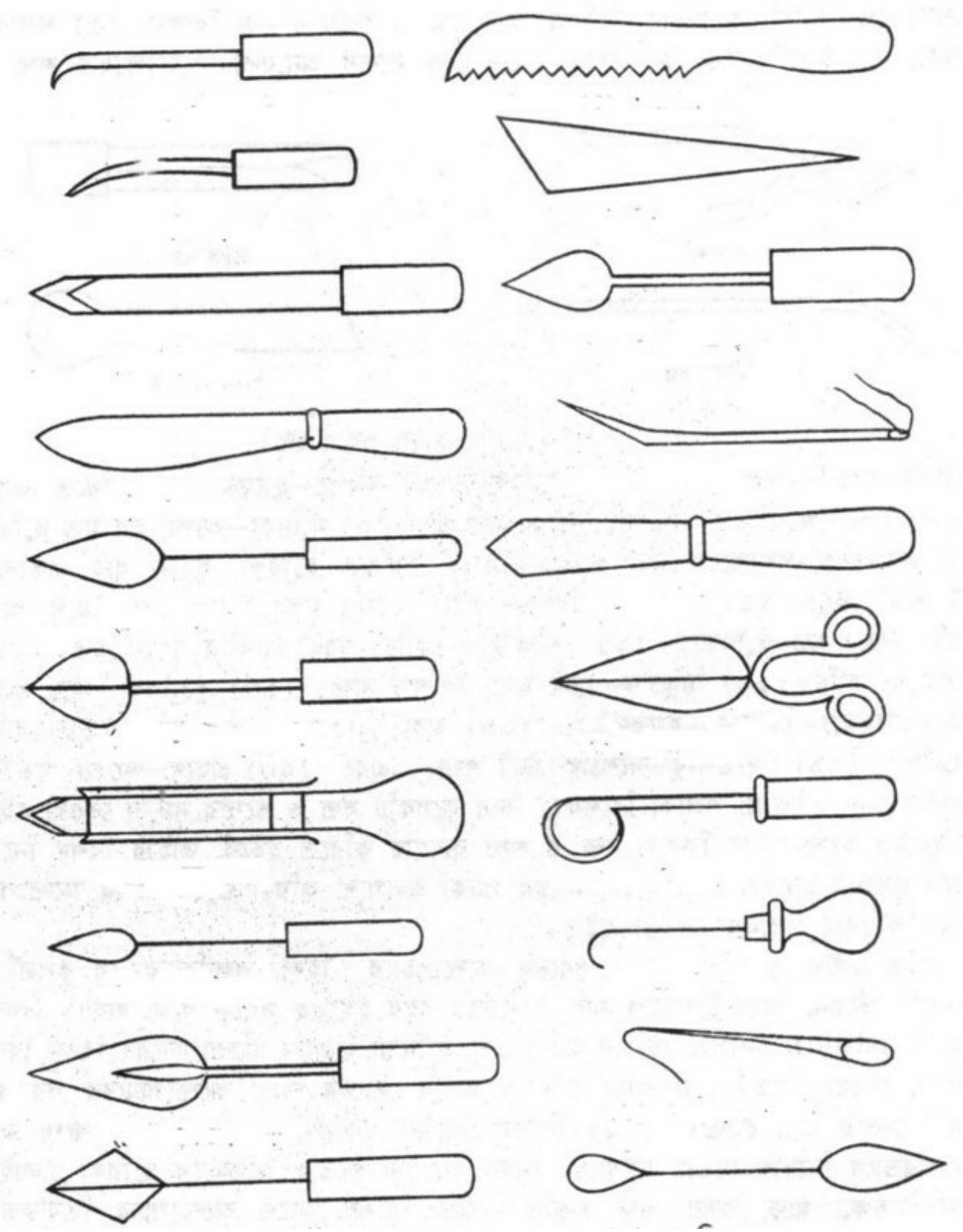

Figure 4.1: Some of the surgical instruments described in the *Susruta Samhita*

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The medicinal treatise *Charaka Samhita* discussed 150 types of diseases with further subdivisions, 341 medicinal plants, 177 medicinal substances of animal origin, and 64 medicinal substances of mineral origin. He also further categorized 102 types of pathological conditions and congenital defects, 109 anatomic and 42 physiological terms and 33 varieties of bones.

He differentiated the cereals and legumes, natural waters, sugar cane derivatives, types of honey, different milk products, different vegetable oils, and alcoholic beverages. This classification was mostly based on the physical characteristics and their utilities.

The most unusual aspect of these is the procedure to re-join severed noses and ears. In those times a common punishment was to cut off the culprit's nose and ears. After this was carried out, if the King learned that the punished person was not really the criminal, then the doctor would receive instruction to re-join the nose and ears. We find a detailed account of the procedure in the writings of both Susruta and Charaka. However we cannot ascertain the success because it is not possible to repeat these procedures experimentally on human subjects in the modern times without violating the laws concerning medical ethics.

However, in the writings of Susruta and Charaka there is no description or instruction on how to place the head of an elephant on a human torso!

4.2 Chemistry

Everywhere the primary motivation in the study of chemistry came from three directions. Medical practice demanded one to know the properties of different kinds of substances and mixtures that could be used for medical purposes. For that reason, wherever medical science had advanced, knowledge about the properties of the substances that have some medicinal use also advanced hand-in-hand. Second, the demands of metallurgy have induced man to experiment with dierent metals and their alloys in an attempt to obtain harder and non-brittle material. Third, the belief that it is possible to transform other substances into gold by chemical processes also prompted man to try out various things. In India the studies in chemistry were initiated from all these angles. Since medical science and metallurgy significantly advanced in this region, it is expected that knowledge of chemistry also must have advanced in step. That is what had actually happened.

Susruta Samhita and *Charaka Samhita* describe the properties of six metals - iron, tin, lead, copper, gold, and silver. They also give elaborate procedures for preparing mild and strong alkaline substances (potassium carbonate and sodium carbonate) which were used to treat wounds. Books written in the later periods also mention the use of mercury, zinc, and sulphur. *Susruta Samhita* mentions a few fermentation products that were applied during operations, probably as anesthetics. Five kinds of salts are described by Charaka. These are *sauvarchala* (nitre), *saindhava* (rock salt), *vit* (black salt), *audbhida* (vegetable salt) and *samudra* (sea salt).

Charaka apparently was influenced by the *Lokayata* philosophy, because, according to him, all objects are the results of the combination of five elements, viz., water, re, earth, air, and ether or space.

Nagarjuna (around 100 AD) was the founder of alchemy and claimed to be able to transmute base metals into gold. Indian alchemy had two characteristic streams: gold making and elixir synthesis, and he wrote about both. Textual masterpieces like *Rasa Ratnakara*, *Rashrudaya* and *Rasendramangala* are his renowned contributions to the science of chemistry. As the author of medical books like *Arogyamanjari* and *Yogasara* he also made significant contributions to the field of curative medicine. Metal and medicinal plant combinations and preparations started with Nagarjuna.

8th century to 16th century was the period where *Rasa sastra* classics were written by many scholars or alchemists. Among them Vagbhata, Nityanatha, Manthana Bhairava, Soma Deva, Yasodhara, Chakrapani, Basavaraju etc. were well known. Even after the decline of science in India that started in the 9th-10th centuries, the cultivation of alchemy continued. But by then chemistry had become a part of mystic practices or *tantravidya* . That is why modern chemistry could not take birth from that. A detailed account of this knowledge can be found in Acharya Prafulla Chandra Ray's famous book "The History of Hindu Chemistry".

Metallurgy has a very rich tradition in India. The extraction of metals from ores and the mixing of different metals to obtain brass and steel of the required strength demanded people to experiment with various ingredients and processes. There is evidence about the use of copper in early days in India in the form of coins by Greek and Bactrian kings of the 3rd century BC as well as by the Kushan king Kanishka and his successors in the 2nd century BC and later by the Gupta kings. The discoveries at Taxila leave no doubt that metal works flourished in India in the first millennium BC and that the metallurgical skill had attained a high level during this

epoch. A large number of iron implements and weapons in the form of swords, daggers, tridents, spears, hangers, lamps, beam rods, and tripods were unearthed during the excavations in the Tirunelveli district of Tamil Nadu. These are products of the 4th century BC. Similar objects were also found in Taxila, which dated from the 3rd century BC to the 5th century AD. A process called "killing" metals is described in some books, which is nothing but reactions that produce substances whose properties are different from those of the original metal.

Since all weapons are made of metals, this pursuit had patronage of the kings. That is why, even though the cultivation of knowledge subsided in India after the 10th century, the art of metallurgy could advance more or less unhindered for a long time. In many archaeological sites we see instances of specific metals prepared for specific purposes.

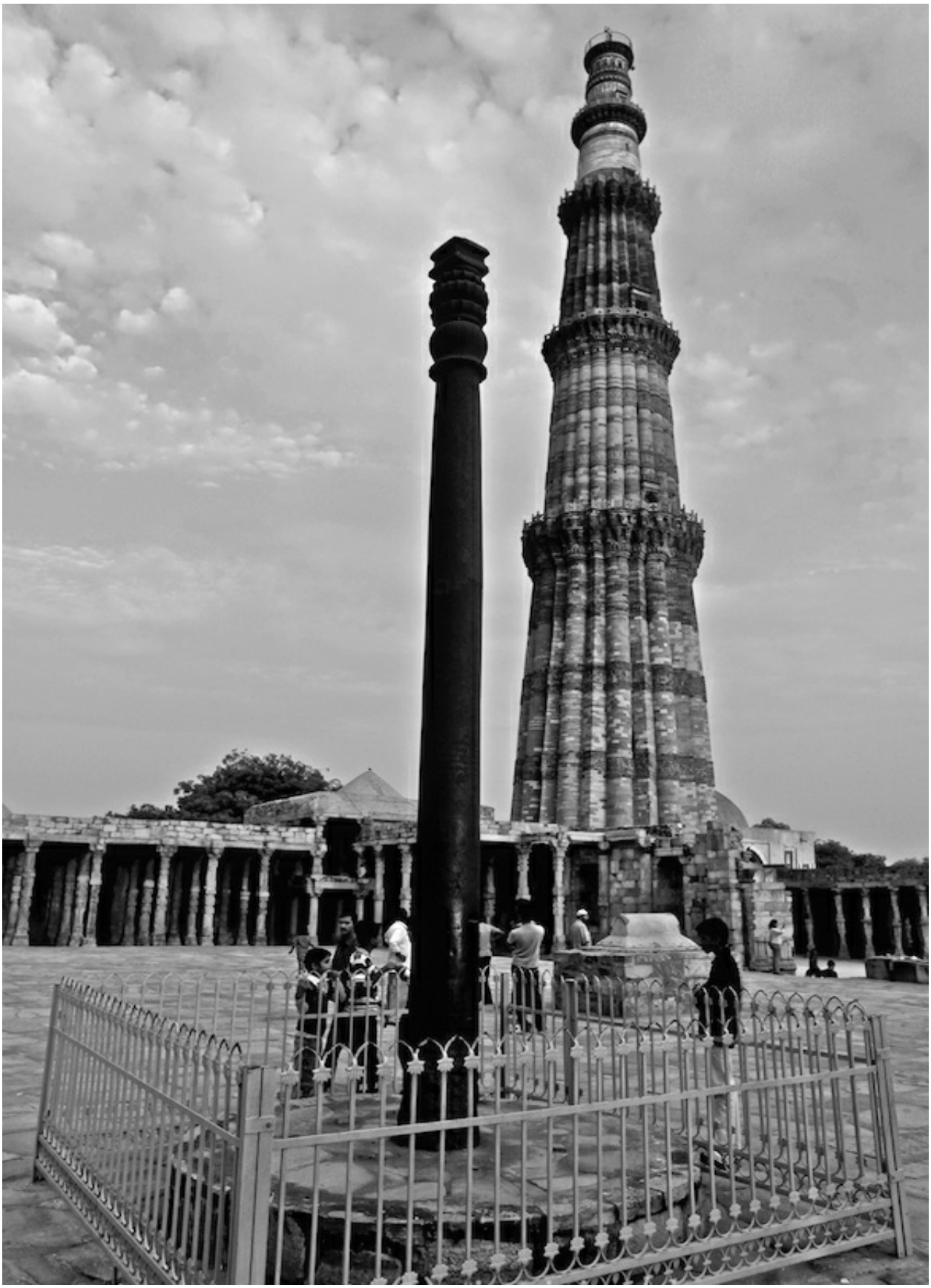

Figure 4.2: The iron pillar in the precinct of the Qutub Minar, Delhi.

Out of these the famous iron pillar located in the compound of the Qutub Minar in Delhi (Fig. 4.2) demands special mention. The 24 foot tall pillar built in the 4th century AD has not rusted as yet. The preparation of the specific kind of metal and the technology of fashioning such a huge pillar are truly examples of technical excellence reached during the Gupta dynasty. But the fringe groups go a bit far in claiming that modern science has not advanced enough to produce rust-less steel similar to that produced by the ancients. This is however not a fact. Scientists have examined the composition of that iron and have found that it has excessive quantities of phosphorous. This is not surprising, since phosphorous is naturally present in the iron ore and gets mixed with iron in the process of its extraction. Even though phosphorus prevents rusting, this phosphorus is removed by reacting with oxygen in the modern steel-making process, because phosphorus makes steel brittle. But for such a large pillar, it does not matter if the material is brittle, because the bulk holds it together. The iron for the pillar was prepared without removing the phosphorus, and that is why it does not rust. But the same material cannot be used to make swords, for which they adopted a different technique.

The technology of producing Wootz steel which was renowned for making swords with exceptional sharpness and toughness originated in India. This was exported to Europe and the Middle East where it was known as Damascus steel.

Another important Indian contribution to metallurgy was in the isolation, distillation and use of zinc. There is evidence of zinc ore mining at Zawar in Rajasthan from the fifth century BC. The earliest confirmed evidence of zinc smelting by distillation dates back to 9th century from Zawar.

4.3 Linguistics

It is known that Sanskrit was not a spoken language. It is a language created by 'purifying' the spoken languages like Pali, Prakrit etc. Such purification itself is a feat in linguistics. But in the early stage, when the Vedas were initially composed, there was no standardization in its form. The feat of standardizing the language by extracting the rules of its grammar was performed by Panini (4th century BC), considered the greatest grammarian of antiquity. Because of this contribution, Sanskrit became easier to learn and post-Panini Sanskrit became the common medium of discourse and exchange among the learned section of the people of the

entire subcontinent. The development of this common medium of exchange played a great role in further development of ideas in this multi-lingual region.

Another remarkable achievement of this period is to design the Devnagri alphabets (Fig. 4.3) by arranging the consonants in a 5 5 matrix. This highly scientific way of arranging the alphabets is not found in any other language in the world.

अ आ इ ई उ ऊ
a ā i ī u ū
ऋ ॠ ऌ ॡ
ṛ ṝ ḷ ḹ
ए ऐ ओ औ अं अः
e ai o au aṃ aḥ
क ख ग घ ङ
ka kha ga gha ṅa
च छ ज झ ञ
ca cha ja jha ña
ट ठ ड ढ ण
ṭa ṭha ḍa ḍha ṇa
त थ द ध न
ta tha da dha na
प फ ब भ म
pa pha ba bha ma
य र ल व
ya ra la va
श ष स ह
śa ṣa sa ha

Figure 4.3: The Devnagri alphabet. The 4th row to the 8th row show the arrangement in 5 x 5 matrix depending on which part of the mouth is touched by the tongue and how much air is exhaled while pronouncing an alphabet.

4.4 Astronomy

We have already discussed the advances in astronomy during the Vedic age, which are found in texts like the *Brahmana* literature, and the *Vedanga Jyotisha* . In astronomy, we do not see any major work in the late Vedic period, and the rst signs of resurgence in the post-Vedic period are visible in the texts written between 100 and 500 AD, which are collectively named as *Siddhanta-Jyotisha* . The *Siddhanta Jyotisha* is not one book. It is actually a common name given to a large number of books (like *Surya-siddhanta, Pitamaha-siddhanta, Vashista-siddanta* , etc.) of similar content. Out of these some books like the *Romaka-siddhanta, Poulish-siddhanta, Yavana-siddhanta* contain ideas culled from Greek and Roman astronomy of the post-Alexander period. These resulted from the opening of trade routes between India and Europe following Alexander's invasion, and the cultural exchanges resulting from that. It is in these books that astrology appears for the first time in Indian literature while the belief in fate governed by planetary positions existed in Greek and Roman literature earlier; so the superstition seems to have been imported from the West.

One important aspect of the *Siddhanta-Jyotisha* books is the attempt to find the periodicities of the motion of the sun, the moon, and the planets. But their way of expressing it was different. Today we know the period of revolution of the Earth around the sun is 365.24219 days (the day measured in terms of the Earth's rotation around its own axis), and that of the moon around the Earth is 27.3216 days. But at the time of *Siddhanta-Jyotisha* it was not known that Earth moves around the sun or that it spins around its own axis. People saw the sun going around the Earth, but they noticed that it does not return to exactly the same position at sunrise every day. After every 365 days it comes to more or less the same position, and according to that the year was counted. But they had noticed that the position after 365 days was also not exactly the same. By noticing the shift after every year, they calculated the period after which it would return to exactly the same position. This "periodicity" of the sun's motion was called a *Mahayuga* . According to many *Siddhanta-Jyotisha* books, a *Mahayuga* contains 43,20,000 years. If one calculates the period of revolution of the Earth around the sun from this figure, the length of the year becomes 365.258 days, which is very close to the modern estimate. Similarly they had calculated the periods of the moon and the planets -the period within which the object revolves a whole number of times. These are given in Table 4.1.

The major objects in the sky and their periodicities, as per *Siddhanta-Jyotisha*

Object in the sky	period (in solar years)
Sun	43,20,000
Moon	5,77,53,336
Saturn	1,46,564
Jupiter	3,64,224
Mercury	1,79,37,020
Venus	70,22,388

It is seen that these periods come to be very large numbers, and historians were surprised to see the mention of such large numbers in astronomical literature of that time. Actually, before the invention of the place-value system of writing numbers, there was no way of expressing the periodicity of these bodies other than in whole numbers. That is why this ingenuous way was adopted.

Since Indian kingdoms of that time had trade relations with the kingdoms in Greece, Rome, and Arabia, there was exchange of knowledge between the scholars of these regions. Through these exchanges the knowledge created in India percolated to Greece, Rome, and Persia, and ideas from knowledge-centres like Baghdad, Athens and Alexandria reached India and became integrated into its body of knowledge. We know that the Greek philosopher Eratosthenes of Alexandria (276-194 BC) measured the diameter of the Earth by observing the shadows of vertical sticks in two different places. We see the mention of exactly the same method in *Siddhanta-Jyotisha* .

After the *Siddhanta-Jyotisha* phase, we see the emergence of great astronomer-mathematicians in the Indian subcontinent. They include Aryabhata (5th Century AD), Varahamihira (6th Century AD), Brahmagupta (7th Century AD), and Bhaskaracharya (12th Century AD). The knowledge generated in the early post-

Vedic period coupled with the infusion of ideas from other lands created the conditions for the great surge of astronomy in India.

The motions of the planets as seen from the Earth are not uniform. Sometimes they are fast, sometimes slow, and sometimes they even move in the reverse direction. To explain such peculiar motion, the Greek astronomer Ptolemy (90-168 AD) had proposed that these do not move around the Earth in circles, rather there are circles over circles - called epicycles. In Aryabhata we see a similar explanation of planetary motion, based on two epicycles.

With Aryabhata we see the start of what is known as *Siddhantic* astronomy. The word *siddhanta* means conclusionthat whose end is established. The characteristic of *Siddhantic* astronomy is the attempt to calculate the position of planets and stars based on mathematical techniques: algebra, geometry, and trigonometry. That is why we see astronomy and mathematics develop hand in hand in this period.

It is remarkable that Aryabhata was the first to talk about the spin of the Earth about its own axis. This means he was the rst to guess that the sun is not really moving around the Earth; rather we see it moving because the Earth itself is spinning about its own axis. But this idea was not accepted by other eminent scholars like Brahmagupta and Varahamihira, who criticised Aryabhata for infusing fanciful ideas into astronomy. Even though Aryabhata talked about the diurnal motion of the Earth, he did not reach the same conclusion as Copernicus, as he described planetary motion in the same way as Ptolemy. He, however, gave the correct scientific explanation for the solar and lunar eclipses.

In the following two centuries, the knowledge of *Siddhantic* astronomy was consolidated in the hands of Varahamihira and Brahmagupta. Varahamihira (485 AD to 587 AD) brought together five systems of astronomy in his work *Panchasiddhntika* . Brahmagupta , wrote a compendium of the knowledge of *Siddhantic* astronomy in his famous work *Brahmasphuta Siddhanta* (628 AD).

But the most important contributions to astronomy of the antiquity came from Bhaskaracharya. His astronomical treatise *Grahaganitam* deals with computations of planetary motions and eclipses. The book on spherical astronomy, *Goladhyaya* , is an important theoretical work as it expounded the computational rules of astronomy viewing the sky as a 'celestial sphere'. He improved the formulae and methods adopted by earlier Indian astronomers. The *Karana Kutuhalam* is a smaller astronomical text with ready-to-use tables. His book *Siddantha Siromani* is one of the best and exhaustive texts in Indian astronomy. Because of various simplified

explanations of the underlying theories, it is considered to be the best *Siddhantic text* . Bhaskara was the first to discover the moon's evection (regular variation in the eccentricity of the moon's orbit around the Earth, caused mainly by the sun's attraction), which preceded similar discoveries in the western countries by four centuries. He also developed methods of observational astronomy and described a large number of astronomical instruments in his book *Yantradhyaya* .

In these periods Indian astronomy was truly ahead of the world. But, as we will see later in this book, science in India underwent a decline and fall, and Bhaskara was the last great astronomer of antiquity. The knowledge, however, was not lost, as the books of Indian astronomy were translated into Arabic. Brahmagupta's *Brahmasphuta Siddhanta* was translated by Al Biruni (the Arabic translation was called *Sindh-Hind*). An Arabic scholar referred to as Kanak Al Hindi further helped the interaction by compiling a text called *Zij Al Sindh-Hind* explaining the ideas in this book. The Muslim world continued the tradition and the main occupation of Arabic scholars became the compilation of astronomical tables, called *Zijes* . Many astronomical tables were developed that fell into three categories: *Zij-e-Rashadi* which were based on direct observation, *Zij-e-hisabi* which were based on calculations, and the *Zij-e-Tes'hil* which were the simplified tables.

With the onset of the Renaissance in Europe in the 15th century through the works of Copernicus and Galileo, European astronomy advanced in leaps and bounds through the use of the telescope. It is then that Indian and Arabian astronomy really fell behind.

But during the Muslim rule in India, cultivation of astronomy continued due to the interest of the Muslim rulers who had exposure to astronomy. During the reign of King Firuz Shah Tughluq who ruled in Delhi from 1351 to 1388, many Arabic and Persian *Zijes* were imported. He ordered translation of Arabic books on astronomy into Sanskrit, and his court scholar Mahendra Suri compiled a book on observational astronomy using the astrolabe, called *Yantra-Raja* , by drawing from Arabic sources. During the reign of the Mughal emperor Akbar, the historian Abul Fazl (1551-1602) recorded the existence of 86 *Zijes* in India, and the trend continued through the Mughal period.

Figure 4.4: A view of the Jantar Mantar at Jaipur.

It is interesting to note the brief resurgence astronomy had in medieval India due to the personal interest of Raja Sawai Jai Singh of Jaipur. He was not really a sovereign king. He was a "Mansabdar" with allegiance to the Mughal rulers. While the Mughal rulers displayed the grandeur of their rule by building great palaces and buildings like the Taj Mahal, the subordinate king Jai Singh chose to make his statement through the medium of astronomy and by building observatories. Jai Singh wrote a book on astronomy in 1729, and went on to build two large observatories (called *Jantar Mantar*) - one in Delhi and another in his capital Jaipur (and three smaller ones in Mathura, Ujjain and Varanasi). The Jantar Mantar at Jaipur (Fig. 4.4) really commands respect, because we see here the most elaborate equipment that could be built for naked-eye astronomy. In designing the large masonry-based instruments some of which are of the size of two-storied buildings, he followed the ideas of Arab astronomy, which, as we have seen earlier, drew upon *Siddhantic* astronomy and enriched it further by developing observational instruments. But this knowledge was deficient in one important aspect: by that time the telescope had been in use in Europe for about a hundred years. Even though Jai

Singh knew about its existence, by choosing to count solely on naked-eye astronomy, he was backward even for his time.

In the period of darkness that fell over Indian science over the period from the 10th to the 19th century, a speck of light continued to glow in a distant corner of the Indian subcontinent - in Kerala. Here a "Kerala school of astronomy and mathematics" flourished whose contributions are based on independent inquiry and observations. Almost all of the Kerala School were the followers of Aryabhata. Many interpretations for *Aryabhatiyam, Laghubhaskariyam* and *Mahabhaskariyam* are available in the Kerala School. Parameswara (1360-1455) and Neelakantha Somayaji (1444-1545) are prominent among them. Neelakantha described a heliocentric-like model wherein the ve planets viz., Mercury, Venus, Mars, Jupiter and Saturn move in eccentric orbits around the sun. Then their positions along with that of the sun are obtained as observed from the Earth. This achievement of the Kerala School of astronomy is truly remarkable in the light of the fact that Neelakantha (1444-1545) preceded Copernicus (1473-1543).

4.5 Mathematics

We have already discussed the advances in mathematics during the Vedic age, which are found in texts like *Shulvasutra* , and the *Brahmana* literature. The characteristic feature of Vedic mathematics was that it was developed with the express objective of solving problems related to religious rituals, in preparing altars or *yagna-vedis* . The numbers, as we have seen, did not include zero, and were not based on the place-value system.

In the post-Vedic period, the Jain mathematicians (between 400 BC and 200 BC) further developed the perception of numbers. They were particularly interested in very large numbers, and could conceive infinity. In the writings of the mathematician Pingala (3rd century BC) we see important works on number theory including what are now known as Pascal's triangle and Fibonacci numbers. Important mathematical works of this period are *Surya Prajnapti, Vaishali Ganit, Sthananga Sutra, Anoyogdwar Sutra* , and the *Satkhandagama* . An important aspect of the contribution of the Jain mathematicians was that they freed mathematics from religious and ritualistic motivations, and made it stand on its own ground.

We have learned much about the development of mathematics in the early post-Vedic period from various manuscripts dating from this time. Prominent among them is the *Bakhshali* Manuscript (Fig. 4.5), a mathematical text written on birch

bark which was found near the village of Bakhshali in Pakistan in 1881. Only about 70 pages have survived, and are now kept in the University of Oxford. The manuscript is written in an earlier form of *Sarada* script which was mainly in use from the 8th to the 12th century AD. It is a handbook of rules and illustrative examples together with their solutions. It is devoted mainly to arithmetic and algebra, with just a few problems on geometry and mensuration.

Figure 4.5: Two pages from the Bakhshali manuscript.

The greatest contribution of India in the world of knowledge happened in the post-Vedic period. It was the discovery of zero and the invention of the place-value system of writing numbers.

Writing of numbers requires a basis. In different parts of the world, different bases were used to write numbers. The Babylonians used base 60, the Mayans used base 20. In India, Arabia, and in many other parts of the world, the number system

had base 10 since antiquity. This means that there were 10 number-symbols (1 to 10) to write numbers up to 19 (19 = 10+9). Another symbol representing 20 would be required for writing numbers from 20 to 29, and then it would require another symbol, so on and so forth. Thus, such a number system would require a large number of symbols to write big numbers. This was the problem with the Brahmi and Kharosthi numbers found in stone tablets of Ashoka's time. The same was the problem of the Roman number system. If you try to write a number like 3905 in Roman script, you would realize the difficulty. The difficulty is clearer when you try to multiply two such numbers written in Roman script.

But today we write arbitrarily big numbers with ease, with only 10 number symbols. This has been possible due to two major discoveries that happened in India. The first was the realization that the absence of something, or zero, is also a number. The second was the invention of the place value system. In the modern decimal system of writing numbers when we write 3905, we actually construct it as

$$3 \times 10^3 + 9 \times 10^2 + 0 \times 10^1 + 5 \times 10^0$$

A time scale of mathematics in India

Sulvasutras	(800BC-200BC)
Pingala	(200 BC)
Jain Mathematicians	(400BC -- 200AD)
Bhakshali Manuscript	(4th Century AD)
Aryabhata	(5th Century AD)
Varahamihira	(6th Century AD)
Brahmagupta	(7th Century AD)
Mahavira	(9th Century AD)
Munjal	(9th century AD)
Sripati	(10th century AD)
Sridhara	(11th century AD)
Bhaskaracharya	(12th Century AD)
Kerala mathematicians	(14-16th Century AD)
Srinivasa Ramanujan	(1887 -- 1920)

Here a digit assumes a 'value', a power of 10, depending on the position where the digit is written. This system of writing numbers was developed in India. The literature of that time shows that this way of writing numbers was started sometime between the 1st and 3rd centuries AD. Zero may have been discovered a century or two before that, because the place value system is not possible without the use of zero. We see the use of the place value system in Aryabhata and the later mathematicians like Brahmagupta and Varahamihira. Their writings were translated into Arabic, through which the Arabs came to know of this system. The Arab world

was very fast in adopting it. Through them, it reached Europe. That is why the decimal numerals are still called the 'Arabic' numbers, even though the system was invented in India. About this giant step forward, the great scientist Albert Einstein said "We owe a lot to Indians, who taught us how to count, without which no worthwhile scientific discovery could have been made."

The time scale of Indian mathematics given in Table 4.2 shows concentrated activity in the period from the time of Aryabhata (5th Century AD) to the time of Bhaskaracharya (12th century AD). This is the period of great advancement of science in India. In this period the major contributions were mainly in four areas: arithmetic, algebra, trigonometry, and number theory. The contribution of the ancient Greeks in mathematics is restricted to geometry. They could not advance much in arithmetic and algebra because they could not invent zero and the place value system. In contrast, the Indian mathematicians did not have this handicap, and so could progress significantly in these directions.

Arithmetic

With the introduction of a new number system, society faced a new problem. None of the old methods of adding, subtracting, multiplying and dividing numbers would be applicable to the new number system. So one had to freshly develop the methods of arithmetic, suitable for this new number system. At that time many techniques were invented, some of which have come to be adopted universally - the ones that students learn in school today.

The spread of the Indian numeral system

It is worth quoting from a speech delivered by the Nobel Prize winning Pakistani physicist Dr. Abdus Salam [5]:

"Almost twelve hundred years ago, Abdullah Al Mansur, the second Abbasid Caliph, celebrated the founding of his new Capital, Baghdad, by inaugurating an international scientific conference. To this conference were invited Greek, Nestorian, Byzantine, Jewish, as well as Hindu scholars. From this conference, the first international conference in an Arab country, dates the systematic renaissance of science associated with Islam. The theme of the conference was observational astronomy. Al Mansur was interested in more accurate astronomical tables than available then. He wanted, and he ordered at the conference, a better determination of the circumference of the Earth. No one realized it then, but there was read at the conference a paper destined to change the whole course of mathematical thinking. This was a paper read by the Hindu astronomer, Kankah, on Hindu numerals, then unknown to anyone outside India."

Algebra

In mathematics India made big contribution in algebra. The unknown quantity (x in modern algebra) used to be written in Devnagri script using the alphabet "*ya* ", or if two unknown quantities were involved, using the first letters of Sanskrit words for different colours. They used to write equations using these notations, and proceeded to solve many of these equations. Much of the Indian contribution to algebra concerns linear and quadratic equations. Brahmagupta (628 AD) gave the first explicit solution of the quadratic equations. Later it was systematized by Sridhar Acharya in the eleventh century, to yield the form

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Trigonometry

In trigonometry also, we see significant advancement. Aryabhata introduced a number of trigonometric functions. Varahamihira gave a table of the sines and cosines (he called *jya* and *ko-jya*) in his book *Panchasiddahntika* . From his and

Brahmagupta's writings we see that many trigonometric relations taught at school today were known in their time. Bhaskara obtained the sines and cosines of even smaller angles, for example he gives

$$\sin 1^\circ = \frac{10}{573}, \quad \cos 1^\circ = \frac{6565}{6569}.$$

Note, however, that the Greek astronomer Hipparchus (2nd century BC) was the first to prepare a sine table and to use it for astronomical calculations.

Figure 4.6: A page from Bhaskara's writings.

Number Theory

In his book *Aryabhatiya* written in 499 AD, Aryabhata made many contributions in mathematics, including square root and cube roots of numbers, arithmetic progression, solution of simultaneous equations, etc. We also see treatments of infinite series including formulae like

$$1^2 + 2^2 + 3^2 + \cdots + n^2 = \frac{n(n+1)(2n+1)}{6}$$

In number theory great advancements were made through solutions of indeterminate equations. When an equation has two unknowns, it is not possible to obtain the values of the unknown quantities. But Brahmagupta, Sripati and Bhaskara showed that in particular situations, such as when the quantities to be found are whole numbers, it is possible to find solutions. Brahmagupta gave a general solution to the linear Diophantine equation

$$ax + by = c$$

where a, b, and c are integers. The solution of second order indeterminate equations of the form

$$Nx^2 + 1 = y^2$$

(called Pell's equation) using whole numbers is considered one of the greatest contributions in number theory. Bhaskara developed an algorithm called *Chakravala* for solving indeterminate equations like the Pell's equation in a systematic way. Bhaskara illustrated the Chakravala with difficult numerals N= 61 and N= 67. He showed that for $61x^2 + 1 = y^2$, the smallest solution in positive integers is x= 226153980, y= 1766319049 (for $60x^2 + 1 = y^2$, it is x= 4 and y= 31).

In 1657, the famous French mathematician Pierre de Fermat sent a problem to his friend Bernard Frenicle de Bessy. The problem asked for integer-valued solution for the equation $61x^2 + 1 = y^2$. They could not solve it, and it was only in 1732 that another great mathematician, Leonhard Euler, solved it. The equation was mistakenly attributed to the English mathematician John Pell (1611-1685) by Euler. However, it is now realized that the problem had been solved way back in 1150 by Bhaskara II, who gave the smallest such numbers as x= 226153980 and y= 1766319049 using the *Chakravala* method [5]. Hermann Hankel, a famous German mathematician, says "Bhaskara's *Chakravala* method is beyond all praise: It is certainly the finest thing achieved in the theory of numbers before Lagrange." Another great mathematician Andre Weil remarks: "What would have been Fermat's astonishment if some missionary, just back from India had told him that his problem had been successfully tackled there by native mathematicians almost five centuries earlier!"

Mensuration

Indian contribution in geometry is meagre, mostly confined to mensuration. We see rules of finding the areas of rectangles and triangles in the writings of Aryabhata

and Brahmagupta. Brahmagupta also gave a formula for the area of a cyclic quadrilateral (whose diagonals are perpendicular to each other). Even though the value of π (pi) is stated as $\sqrt{10}$ in some *Siddhanta Jyotisha* manuscripts, people like Aryabhata succeeded in obtaining it in much greater accuracy: 3.1416 (though he actually expressed it as a rational ratio).

As we have stated earlier, there was a decline and fall of Indian science which started in the 9th-10th centuries. As in astronomy, in mathematics also Bhaskara was the last torch bearer of the *Siddhantic* tradition.

However, when doom spelt almost all over India, in Kerala there developed a school of mathematics and astronomy in the period from 14th to 16th century AD which made significant advances in astronomy and mathematics, including fields such as trigonometry and analysis. Madhava made important contributions to the field of infinite series and provided the first example of a power series. Rudiments of calculus are also present in the works of Jyeshthadeva, but the Kerala mathematicians did not really formulate a systematic theory of differentiation and integration. This had to wait till the advent of Newton and Leibniz.

4.6 The Centres of Learning

In the Vedic age the way of imparting education was personal. A learned person or sage would teach a handful of students in his own home. The students lived for a few years with the teacher, gave service in the teacher's home and field, looked after the cattle, and in return got an education. But in the Buddhist period, the *Stupas* and *Mutts* started emerging as centres of learning, where a large number of monks and *bhikkhus* lived together and exchanged knowledge.

This model slowly caught on, and a number of specialized centres of learning emerged where a large number of teachers and students lived in a compound, and the teachers could teach a larger number of students. The oldest of these is situated in Takshashila, the capital of Gandhara (present Kandahar province in East Afghanistan) which started developing from a time slightly before Buddha, but reached glory during the Buddhist period. Later, in the 5th century AD, another centre of learning was established in Nalanda with the patronage of the Magadh kings. Even though these two were the most famous, many more relatively smaller centres of learning have been found, like Pushpagiri in Odisha, Odantapuri and Vikramshila in Bihar, Jagaddal in Bengal, Balavi in Gujarat, etc. Some of these were so famous that students came from far-away places like China.

In these centres of learning, education was imparted in an organized manner somewhat like the Buddhist monasteries. However, the form and content of education were personal in nature. The residential facilities and class-rooms in these centres of learning enabled a teacher to teach 20-30 students at a time depending on one's ability and fame, and facilitated exchange of ideas among many scholars. These centres of learning were undoubtedly great initiatives in ancient India that helped knowledge to be consolidated and expanded.

Chapter 5

The Decline of Science in India

In spite of such a rich and glorious tradition, there was a setback in the cultivation of science after the 9th-10th century, after which it completely died out. Bhaskara can be said to be the last spark of light before it became dark. After him for more than 800 years, there was practically no contribution to science coming from India (except for the few exceptional cases mentioned earlier).

What was the reason behind the decline and fall of Indian science? The famous 19th century chemist Acharya Prafulla Chandra Ray investigated this issue in his book "The History of Hindu Chemistry". According to him, three factors were responsible for this decline in the cultivation of science.

The first was the introduction of the caste system in a rigid form. According to him, the interaction and exchange of ideas between the doers and the thinkers is an essential precondition for the cultivation of science, and casteism blocked this process. "The arts being thus relegated to the low castes and the professions made hereditary, a certain degree of fineness, delicacy and deftness in manipulation was no doubt secured, but this was done at a terrible cost. The intellectual portion of the community being thus withdrawn from active participation in the arts, the how and why of phenomena - the coordination of cause and effect - were lost sight of - the spirit of enquiry gradually died out among a nation naturally prone to speculation and metaphysical subtleties and India for once bade adieu to experimental and inductive sciences. Her soil was rendered mortally unfit for the birth of a Boyle, a DesCartes or a Newton and her very name was all but expunged from the map of the scientific world."

The second reason was the introduction of the "*shastras* " or moral code books that specified what can and cannot be done[3] . "The drift of Manu and of the later *Puranas* is in the direction of glorifying the priestly class, which set up most arrogant and outrageous pretensions. According to Susruta, the dissection of dead bodies is a *sine qua non* to the student of surgery and his high authority lays particular stress on knowledge gained from experiment and observation. But Manu would have none of it. The very touch of a corpse, according to Manu, is enough to bring contamination to the sacred person of a Brahmin. Thus we find that shortly after the time of *Vagbhata* , the handling of a lancet was discouraged and Anatomy and Surgery fell into disuse and became to all intents and purposes lost sciences to

the Hindus."

The third reason was the influence of the *Vedanta* philosophy, which taught people to see the material world as *maya* or illusion, on the learned section of the people. "The Vadanta philosophy, as modified and expanded by Shankara, which teaches the unreality of the material world, is also to a large extent responsible for bringing the study of physical science into disrepute. Shankara is unsparing in his strictures on Kanada and his system. One or two extracts from Shankara's commentary on the *Vedanta Sutras* , will make the point clear." Thus, according to Acharya P. C. Ray, a scientist's queries are directed at the material world, its processes, phenomena and events. If one sees the material world as *maya* or illusion, one cannot do any science. The spread and intellectual dominance of the Vedanta philosophy as propagated by its powerful exponent Shankara (8th century AD), was responsible for the weakening of the materialistic philosophies like *Lokayata* , and for the death of science in India.

Chapter 6

Debunking the false claims

6.1 Did the Muslim Invasion Destroy the Scientific Tradition?

In recent times it is being claimed that the reason behind the decline and fall of Indian science were the Muslim invasions. It is said that the Muslim rulers destroyed the scientific books and institutions, resulting in the decline of science. We have seen that the great scientist Acharya Prafulla Chandra Ray attributed entirely different reasons to the decline of science in India. But is it factually true that the Muslim rule had a negative influence on the cultivation of science?

To seek the answer, let us first look at the relationship between the two cultures. It was the Muslim scholar Al-Khwarizmi who took zero and the place value system to the Islamic world, and Europe got to know about it in the 12th century through Arab texts! In the 9th century, translations of Sushrutha and Charaka Samhita appeared in Arabic. Ayurveda was partly absorbed into Arabic medicine. The great scholar Al Biruni learned Sanskrit in exile and translated Brahmagupta's book (*Sindh-Hind*) in the year 1035. The book is an encyclopaedic treatise on Indian sciences, philosophy and astronomy. The efforts of Al-Khwarizmi and Al-Biruni resulted in an exchange of ideas between the two cultures and the Arab world looked at Indian science with respect and drew inspiration from its developments. In this background, is it believable that, when Muslim rulers came to India, they would destroy the things that their own scholars revered so deeply?

The second issue concerns timing. We have seen that the decline of Indian science started in the 9th-10th centuries and was practically dead after the 12th century. Yet, at that time the Muslim rulers were only making inroads through the Western fringes and had not yet established themselves in a major part of the subcontinent. The first conquest happened in the early 11th century, when Mahmud of Ghazni defeated Raja Jayapala of the Hindu Shahi Dynasty of Gandhara (in modern Afghanistan), and advanced as far as Peshawar (now in Pakistan). In 1173, Muhammad Ghori launched an offensive from the Ghor region of Afghanistan and by 1187 defeated the Ghazni rulers. In 1192 he defeated Prithviraj of Ajmer and expanded his empire to a part of western India. Delhi Sultanate was founded by his successors around 1206. QutbUd Din Aibak, a slave of Ghori, became the first Sultan of Delhi. Timurlane invaded Delhi in 1398. He looted, plundered, but did not establish a rule there. Babur Shah entered India in 1526 and established the Mughal

dynasty. The Mughal Empire succeeded in conquering much of India.

Thus we see that the Muslim rulers were not ruling much of India during the onset of the decline of science. It was only in the 13th century that the Delhi Sultanate was first established, and the Mughals set foot only in the 16th century.

Thus, there is every reason to believe that the reason behind the decline and fall of Indian science was internal. There is no point in blaming an imaginary culprit.

6.2 Are Ramayana, Mahabharata great literature or historical facts?

The fringe groups are claiming that the great epics *Ramayana* and *Mahabharata* , and the *Puranas* are actually historical facts. That is why a critical study is necessary to ascertain if these are really elements of history or great literature.

Let us first suppose that the events described in these epics did really happen sometime in the past. If that be so, there should be only one account of the events. But in fact various versions of these stories are in circulation in various parts of India. There are multiple evidences pointing to the fact that these epics were not written by individuals - Valmiki in case of *Ramayana* and Vedvyas in case of the *Mahabharata* - but actually developed over very long periods of time.

The Bhandarkar Oriental Research Institute, Pune, had conducted a critical study of the *Mahabharata* and *Ramayana* which was published in 1966. The study revealed that *Mahabharata* evolved over a period of 1000 years (800 BC to 200 AD) in 3 Stages, and the length of the text also increased as new passages were added by narrators. The stages were:

(a) Jaya (before 800 BC) : 2400 lines
(b) Bharata (800 BC to 400 BC) : 24000 lines
(c) Mahabharata (400 BC to 200 AD) : 1,24,000 lines

The first of these, *Jaya* , was a tale of warfare between two clans and the heroics of the warriors - a simple *kshatriya* story. In the next stage, new side-stories expounding values like compassion, forgiveness, truthfulness, self-restraint, etc., were added in order to use this popular story as a vehicle for conveying the moral values necessary for the society. These side-stories already existed in different forms in different regions as folk-tales, glimpses of these are also found in the Buddhist, Jain, and Brahmana literature. These additions, occurring over a period of about eight centuries, finally gave the shape of *Mahabharata* as we know now.

It was found that the vocabulary and grammar in different *shlokas* were significantly different, indicating that they were written in dierent times, the language reflecting the usage current in each period. The last addition seems to be the *Gita* , as its language is the most modern.

And when a story develops over a millennium with different authors adding parts, some inconsistency is natural to creep in. There are many such instances in the *Mahabharata* . As an example, take the names of the warring clans - the *Kourava* and the *Pandava* . According to the story, King Kuru was the founder of the dynasty and somewhere down the line we have Shantanu and his son Vichitravirya. Vichitravirya's two sons were Dhritarashtra and Pandu. Thus, as per the prevailing convention, the progeny of both Dhritarashtra and Pandu are supposed to be called the Kauravas, because they all belong to the Kuru clan. Yet, we see that only the sons of Dhritarashtra were called the Kauravas and those of Pandu were called Pandavas. Why?

The study by the Bhandarkar Institute revealed that the storyline was not always what it is now. In the first two stages (*Jaya* and *Bharata*), the war was between the *Kouravas* and the *Panchals* - and the sons of Pandu (the *Pandavas*) joined hands with the *Panchals* . In the last stage (*Mahabharata*) the storyline changed: it became *Kourava-Pandava* war, with the *Panchals* joining the *Pandavas* . But the same nomenclature continued into the new storyline.

Similarly, the epic *Ramayana* evolved over a long period from 400 BC to 400 AD. The basic mythology involving a story of the abduction and rescue of a heroine can be found over a large geographical extent, spread from Indonesia to Ireland. Originally it had six *Kandas* (Parts), one more *Kanda* was added later. The famous linguist Dr. Sukumar Sen has shown that three stories taken from the Buddhist *Jataka* , one story from Jain literature, and one story from Iranian Khotanese language have been integrated into the *Ramayana* epic.

To the point of fact, the places that bear names related to the *Mahabharata* and *Ramayana* - like the town of Kurukshetra in Haryana, Ayodhya in UP, or the country Sri Lanka - have no historical significance. There have been a number of archaeological excavations in Kurukhetra, and yet no archaeological evidence has been found - no spear, no arrow, not a single wheel of a chariot (*ratha*). Similar excavations in Ayodhya have also revealed nothing. Not a single weapon or ancient building has been found.

But what about the mention of great weapons like the *Pashupat Astra* or

Shaktishel ? What about the mention of the *Pushpak Ratha* that could fly in the sky? What about the mention of giants (*danavas* and *rakshashas*) and *vanaras* (monkeys)? Didn't these really exist?

The fact is, such imagery is a part of all epics. The great Greek epics Iliad and Odyssey have similar imageries. But there is always some basis on which imagination is built. People saw bows and arrows. They imagined large mighty bows and arrows and gave them grand names - *Pashupat Astra , Brahmastra* , etc. People saw horse-drawn chariots. They also saw birds flying in the sky. In their imagination they combined the two and imagined the flying chariot (*Pushpak ratha*). People saw large men and small men. In their imagination they created very large bodies (*danavas*). Fact of the time was the Aryan versus non-Aryan conflict. The Aryans did not see the non-Aryans in good light. In the imagination of the Aryans the non-Aryans were depicted as demons (*asuras* and *rakshashas*), and if they cooperated with the Aryans, as monkeys (*vanaras*).

It should be noted that such imageries were integral part of the storylines. If stripped of these imageries, the epics would become uninteresting monotonous narratives. One should enjoy the imagery, all the while keeping in mind that these are imageries, not actual historical facts.

6.3 Were there flying machines in ancient India?

In addition to the above, many other wild claims are being made in different forums. Importantly, the following claims were made in the Indian Science Congress held in Mumbai from 3rd to 7th January 2015.

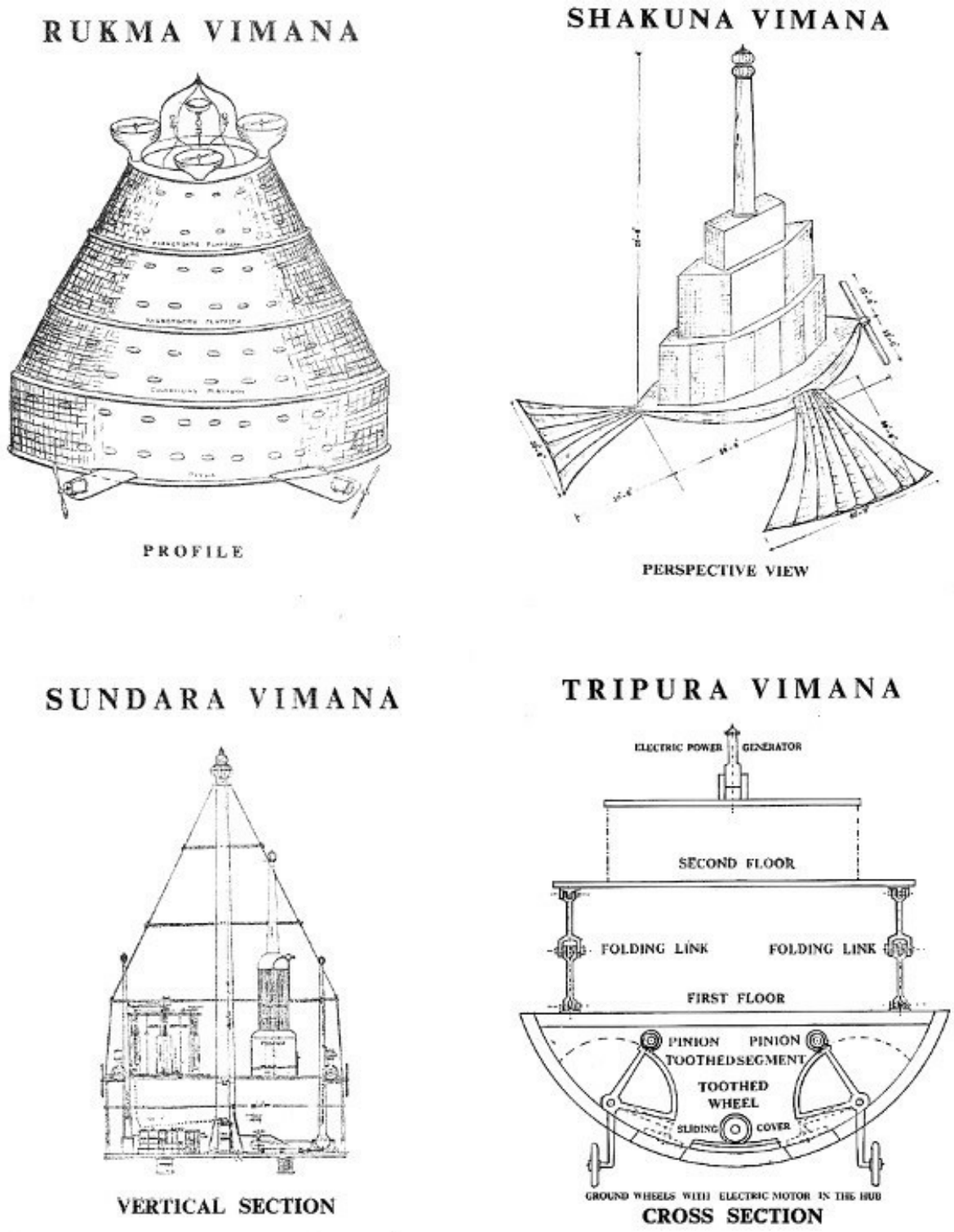

Figure 6.1: The sketches of the so-called *Rukma Vimana*, *Shakuna Vimana*,

Sundara Vimana, and Tripura Vimana.

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1. Ancient Indian sages built cars and airplanes in Vedic period around 7000 years ago.
2. Those planes could move forward as well as backward and in left and right directions.
3. The planes used mercury vapour, solar energy, as well as atmospheric air as fuel.
4. These planes could travel not only from one country to other but also to other planets.
5. Some of the planes were over 200 feet. Five-storied *Sundara Vimana* could fly with a speed of 12800 mph with a fuel made of urine of cows and elephants.
6. The pilots' clothes were made of underwater vegetation.

These claims were made on the basis of a book titled *Vaimanika Shastra* claimed to have been written by a mythological figure - Maharshi Bhardwaj. Five scientists of the Aeronautical Engineering Department of the Indian institute of Science, Bangalore - Prof. J. S. Mukund, S. M. Deshpande, H. R. Nagendra, A. Prabhu and S. P. Govindraj - studied the book carefully and wrote a research paper titled, `Critical Study of the Work *Vaimanika Shastra* ', which was published in 1974. They proved that the so called *Vaimanika Shastra* was not written 7000 years ago, rather it was the brain-child of a Sanskrit scholar Subbaraya Shastri who wrote it in 1923! This book was made public in 1951 by Sri A. M. Joysar, the founder of International Sanskrit Academy of Mysore. The sketches of the planes depicted in the book (some of which are shown in Fig. 6.1) were drawn by Sri Alappa, a draftsman of an engineering college of Bangalore and inserted in the English edition of this book in 1973. They proved that it was not possible for those planes to fly according to the laws of aerodynamics and Newton's laws of motion; any plane manufactured based on these ideas would surely have met with a horrible accident.

Earlier in his book *Rigveda Bhaashya Bhoomika* , Maharishi Dayananda Saraswati tried to establish that flying machines existed in India during the Vedic period by citing the following *mantra* :

⋯ *Trayah skambhaasah skabhitaasah aarabhe*

trirnaktam yaathastrirvityashwinaa diwaa

(*Rig. ashta 1; adh. 3; varga 4; man.2*)

He translates it as "⋯ going from one island to another with these (air-) crafts in three days and nights ⋯ "

While Dayananda Saraswati sees 'aircraft' in the mantras, it is interesting to see what the celebrated commentator *Saayana* had to say on this *shloka* : "There are three wheels to your honey-bearing chariot as all the gods have known it to be when attending the marriage of Vena, the beloved of Soma; O Ashwins, there are three pillars fixed in the chariot for support and in it thrice you drive by night and thrice by day" [7]. Thus, Dayananda Saraswati had wrongly translated the Sanskrit text to fit his fanciful ideas.

If the claimed aeroplanes really existed at some time in the past, some relics - metallic fragments of the engines, wings, and other components - must be found in the archaeological sites. None has been found so far - not a single broken piece. Again, if ancient India possessed planes and modern war-machinery, why could it not defeat the invaders? There is no answer to such natural questions.

The most important point is that the idea of a technological marvel like an aeroplane does not emerge out of nothing. Only when our understanding of the laws of thermodynamics, aerodynamics, metallurgy and a host of other fields developed to a certain extent, the idea of construction of a flying machine could develop. Ideas from all these fields go into the making of an aircraft. Hence it is not possible for aircraft to exist in ancient India unless the knowledge in these fields developed before that. There is no evidence of any advancement in aerodynamics, thermodynamics etc. in the Vedic literature (interestingly, the proponents have not claimed that also).

Anybody conversant with rudimentary chemistry knows that the urine of cows and elephants cannot be used as fuel. Mercury vapour also cannot be used as fuel because it does not produce heat when it reacts with oxygen. Air aids burning because of the presence of oxygen in it, but cannot itself be used as fuel. Solar energy can provide power for various purposes, but the rate at which solar energy is incident on the Earth's surface (about 1 kW/m^2) is not sufficient to power aircraft made with metal.

The drawings of the aircraft in the book *Vaimanika Shastra* (Fig. 6.1) show propellers. Even if we assume that propellers had been invented by the Vedic sages, they cannot work in vacuum. How can such aircraft fly to other planets?

Anybody conversant with anthropology knows that 7000 years ago man was

still in the stone age. Would the proponents have us believe that the aircraft were made of stone?

6.4 Was the Ram Setu really built by Lord Rama?

According to the *Ramayana* , Lord Rama had built a bridge to reach the island kingdom of *Lanka* with the help of his *vanara-sena* or the army of monkeys. Citing a satellite image of the region between Tamil Nadu and Sri Lanka (Fig. 6.2), the fringe groups are claiming that the mythological *Ram setu* really exists and assert that it is an ancient engineering marvel.

Regarding the so-called `*Ram Setu* ' it may be stated that the Archeological Survey of India has concluded and even reported to the Supreme Court of India that there is no scientific evidence that the *Ram Setu* ever existed. The fringe groups have misinterpreted the images taken by the NASA. Refuting their claims the NASA spokesman Michael Braukus said: "The age, substratum, geological structure or anthropological status of the ocean bed in Palk strait cannot be determined by the astronauts' photographs. So there is no basis for these claims." Another NASA officer Mark Hess said, "Remote sensing images or photographs from orbit cannot provide direct information about the origin or age of a chain of islands, and certainly cannot determine whether humans were involved in producing any of the patterns seen." He added, "The mysterious bridge was nothing more than a 30 km long, naturally-occurring chain of sandbanks called Adam's bridge. NASA had been taking pictures of these shoals for years. Its images had never resulted in any scientific discovery in the area." [Source: Photos no proof of Ram Setu; The Hindustan Times, 14 September - 2007]

Figure 6.2: A satellite picture showing the submerged tombolo between the Southern tip of India and Sri Lanka.

The fact is that such naturally occurring bridges between two land-masses occur at many places in the world (see Fig. 6.3), and are called Tombolo. These form because the ocean currents are impeded by the existence of an island on the way, causing movement of suspended matter like silt and sand from one place to another and deposition at specific places. As waves near an island, they are slowed by the shallow water surrounding it. These waves then bend around the island to the opposite side as they approach. The wave pattern created by this water movement causes a convergence of longshore drift on the opposite side of the island, resulting in deposition of sediments. The beach sediments that are moving by lateral transport

on the lee side of the island will accumulate there. Eventually, when enough sediment has built up, the beach shoreline connects with an island and forms a tombolo.

Figure 6.3: Examples of tombolos in different parts of the world. Would the proponents of "Ram-setu" theory have us believe that these were also constructed by monkey-armies of those lands?

Interestingly, a few videos are being circulated on the website YouTube which claim that the monkey-army built the bridge with the help of stones that float. The videos apparently show a stone floating in water. It is known that all stones have specific gravity greater than that of water, and so stones cannot float. However, there are some rocks formed out of solidification of volcanic material, where air pockets are trapped. Hence these rocks, called geodes, are hollow - giving them a lower specific gravity. But even geodes have specific gravity exceeding that of water, and cannot float - though the possibility exists that in extremely rare circumstances such amount of air may be trapped that may make them float. But abundance of such rocks in sufficient numbers to form a 40 km long bridge is impossible.

Moreover, can one really build bridges with floating rocks? Won't the flowing water move them away and scatter them around as soon as these are placed to float in the ocean? The fringe groups are hoodwinking the people with such videos, shot using artificial material constituting the "rock" (possibly fibre-glass) and/or "water" (probably some transparent liquid with larger density).

6.5 Stem cells, organ transplantation, genetic engineering

Futher claims have been made in dierent quarters. It has been claimed that the birth of one hundred *Kauravas* by Mother Gandhari was possible with the help of `stem cell' technology. It has been claimed that Karna's birth was possible due to development in genetic engineering. It has been claimed that the ancients knew the technology of organ transplantation - how else could an elephant's head be planted on a human torso to give shape to Lord Ganesha?

The claim of organ transplantation in ancient India is baseless, because placing of elephant's head on human body is quite impossible. In spite of the huge development of human knowledge, one cannot defy natural laws. We can only know the natural laws and can use them for the benefit of humankind. The nervous system and the blood circulation system of an elephant and of a man are entirely different. The nerves, veins and arteries are positioned differently. That is why, if one places the head of an elephant on the neck of a man, the nervous pathways and the blood circulation channels cannot be connected, and so this organic transplantation is impossible. Moreover, the ability of an elephant's brain is far inferior to that of the human brain. Even if such a transplant were possible, the resulting being would not be capable of thinking. Even placing a severed human head to a human torso is still not achievable.

Similar are the tales of Kunti's hundred sons and the birth of Karna. These are just mythological stories, and any attempt to find scientific meaning to these leads to many inconsistencies. In *Mahabharata* , the story of Karna's birth goes as follows. As a young woman Kunti had been granted a boon by sage Durvasa to be able to invoke any deity to give her a child. Eager to test the power, while still unmarried, she called upon the solar deity *Surya* and was handed a son Karna wearing armour (*Kavacha*) and a pair of earrings (*Kundala*). Afraid of being an unwed mother and having a bastard, Kunti placed the baby in a basket and set him afloat on a river. Does it sound like she went to a biotechnology laboratory to have the baby?

6.6 And quantum mechanics, particle physics, relativity

It is also being opined in various quarters that most of the ideas of modern science - particularly quantum mechanics, particle physics, electromagnetic theory, and the theory of relativity - were discovered by the Vedic sages many millennia before these were "rediscovered" by modern science. The proponents cite a few Sanskrit *shlokas* which contain words like *kana* (particle), *taranga* (wave), *shakti* (energy), etc.

Prof. S. Balachandra Rao calls these "squeezing science out of the Vedas" [7]. The actual meaning of the Sanskrit texts have no relation with what they are claimed to be in an overzealous spirit of religious revivalism. For example, there is a *Rigveda mantra* :

Yuvam padave puruvaaramashvinaa spridham shwetam

tarutaaram duvasyathah

sharyairabhidyum pritanaasu dushtaram

charkrityamindramiva charshaneesaham

(*Rig Veda Mandala* 1, *Shukta* 119, Man. 10)

From this *shloka* Dayananda Saraswati extracts the meaning "Learn the secret of telegraphy the benefits of which are manifold. It helps to produce quick locomotion to achieve best results. The wire must be made of pure metal charged with electricity. It can be used again and again after charging with electricity." But the actual meaning of the *shloka* is: "O *Ashwi* , you give the king Padu the white horse, which was desired by all and which was capable of defeating the enemies. The unconquerable, brilliant and multi-purpose horse was like Indra who triumphed over men."

Most of the references to ancient texts are of similar nature. Mostly the Sanskrit texts are misrepresented or wrongly translated to fit certain whimsical ideas. In many cases the text only contain words that have commonplace meanings (like "wave" - which could simply mean the waves seen on the surface of a pond, but are lifted out of context to mean electromagnetic waves).

There are two theoretical reasons why these knowledges could not have been obtained in antiquity. Firstly, all developments in science occur on the basis of some earlier knowledge. In order to have an understanding of electromagnetic waves, one has to know the character of electricity as well as of magnetism and the laws governing their mutual interaction. Einstein could formulate the arguments that led

to the theory of relativity based on the knowledge of the Newtonian mechanics and Maxwell's theory of electromagnetism. Quantum mechanics could be developed only after we learned about radioactivity, photoelectricity, and the character of radiation emerging out of heated substances. None of these developments happened in knowledge isolation. In fact, no development in science can happen without the benefit of earlier knowledge. And when the fringe groups make claim of some discovery in the antiquity, they never make any claim on the antecedent discoveries.

Secondly, all these claims come only *after* a particular discovery has been made by modern science. The fringe groups talk about the discovery of atom bombs, aircraft, or theory of fundamental particles only after these discoveries have been made by modern science. If these were really discovered in the antiquity and are available in the Vedic literature, why cannot someone *make* the discoveries using the Vedic texts? Why has that never happened? That is because this knowledge was not there in the antiquity. It cannot be there because knowledge advances progressively, each generation making new advances on the basis of the knowledge gained by the previous generation.

Chapter 7

Conclusion

There was significant cultivation of science in ancient India, but a lion's share of it was done in the period from 6th century BC to about 10th century AD. The contribution of India to the world of knowledge in this period is truly something to be proud of. But this period is not the Vedic period. We also have to keep in mind that the glorious tradition of cultivation of science was halted and nally terminated in India, due to the imposition of a rigid caste system, and due to the *shastras* that dictated what to do and what not to do, and due to the revival of the *Vedanta* philosophy.

The preposterous claims about the science in ancient India - like the claims of aircraft that flew from one planet to another, of surgery to place an elephant's head on a human body, of in-vitro fertilization for giving birth to Karna - will only make Indian science a laughing stock before the rest of the world, and will undermine the actual contributions of India to the world of knowledge. Any right-minded person should defend the actual history and should propagate an awareness of it, and should debunk the ludicrous claims.

Many eminent intellectuals, scientists and historians have come out openly to criticise this attempt of the fringe groups to depict the wrong account of India's past. In a resolution passed in its three-day platinum jubilee session at the Jawaharlal Nehru University, the Indian History Congress called for "defence of scientific method in history". "Unfortunately, even the Prime Minister has suggested that in the hoary past, Indians had learnt, and then forgotten, plastic surgery of a kind going far beyond what is now possible. There is widespread belief that soon textbooks will be revised or rewritten, to inculcate such a strongly misleading and divisive brand of history among pupils in our schools ⋯ It also calls upon all members of the political establishment to refrain from making statements contrary to well-established historical facts. They should understand that loose or irresponsible statements of this kind tarnish the good repute of this country," said the IHC Resolution.

Dr. Ram Prasad Gandhiraman, a scientist at the NASA's Ames Research Centre in California, filed an online petition that said: "We as scientific community should be seriously concerned about the infiltration of pseudo-science in science curricula with backing of influential political parties. Giving a scientific platform for a pseudo-science talk is worse than a systematic attack that has been carried out by

politically powerful pseudo-science propagandists in the recent past. If we scientists remain passive, we are betraying not only the science, but also our children."

Renowned scientist Pushpa M. Bhargava, the founder-Director of the Centre for Cellular and Molecular Biology at Hyderabad, and Chairman of the Southern Regional Centre of Council for Social Development, has remarked that India has not produced any Nobel Prize winner in science in the last 85 years largely because of the lack of a scientific environment in the country.

The Breakthrough Science Society appeals to the people to generate a public awareness of the true contributions of India in the world of science and to resist the attempt of the fringe groups to cultivate an environment of superstitious bigotry in the country.

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[1] Note that the times given in the chart are not sharp starting and ending years. For example, the decline of science started from the 9th-10th centuries and was practically extinguished after the 11th century; that is why the Medieval period is stated to have started from the 11th century.

[2] Does the method shown in Fig. 3.3 really give a circle of the same area? In the figure, let AN be of length a. Therefore the area of the square is $4a^2$. Now, OM =OA =$\sqrt{2}$ a.

MN =OM -ON = ($\sqrt{2}$ - 1)a; NP =MN/3 =($\sqrt{2}$ -1)a/3.

OP=ON+NP={1 +($\sqrt{2}$ - 1)/3}a.

If this is the radius of the circle, its area is $\pi \{1 +(\sqrt{2} -1)/3\}^2 a^2 = 4.069a^2$.
Therefore the Shulvasutra method is good, but not really accurate.

[3] The `Manusmriti' or `Manu Samhita' is the most important ancient text that specied the dos and don'ts of Hindu Dharmashastra.